Modelling Information Age Warfare:

Remaining Challenges

Jim Moffat
Senior Fellow, Dstl

Report Documentation Page

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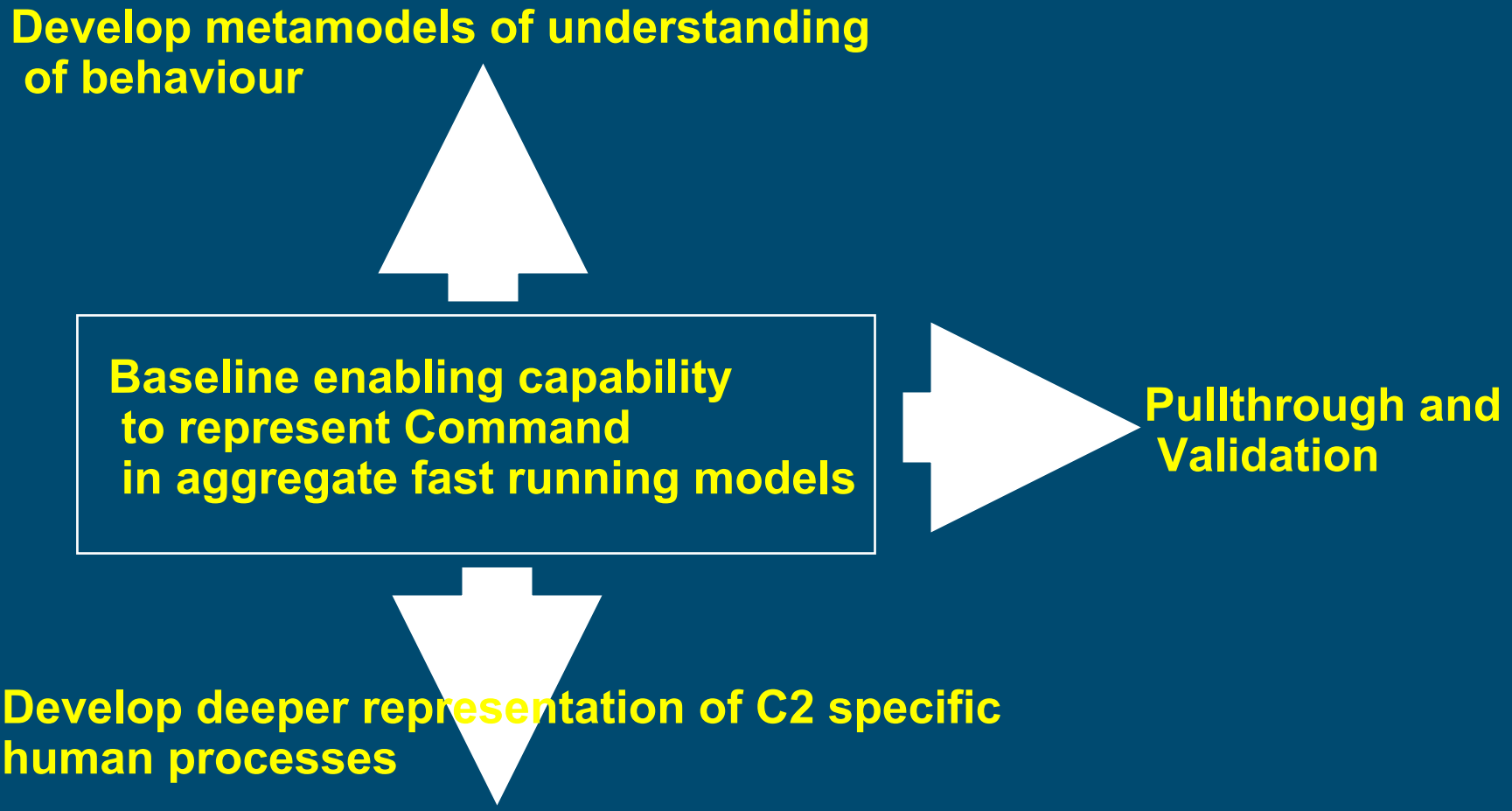
Challenges for the information age

- Quantifying the benefit of good Command
  - command effectiveness/force effectiveness
- Understanding Emergent Behaviour
  - local collaboration/force level effects
- Modelling the clustering of decision makers across an information network
  - local information sharing/collaboration

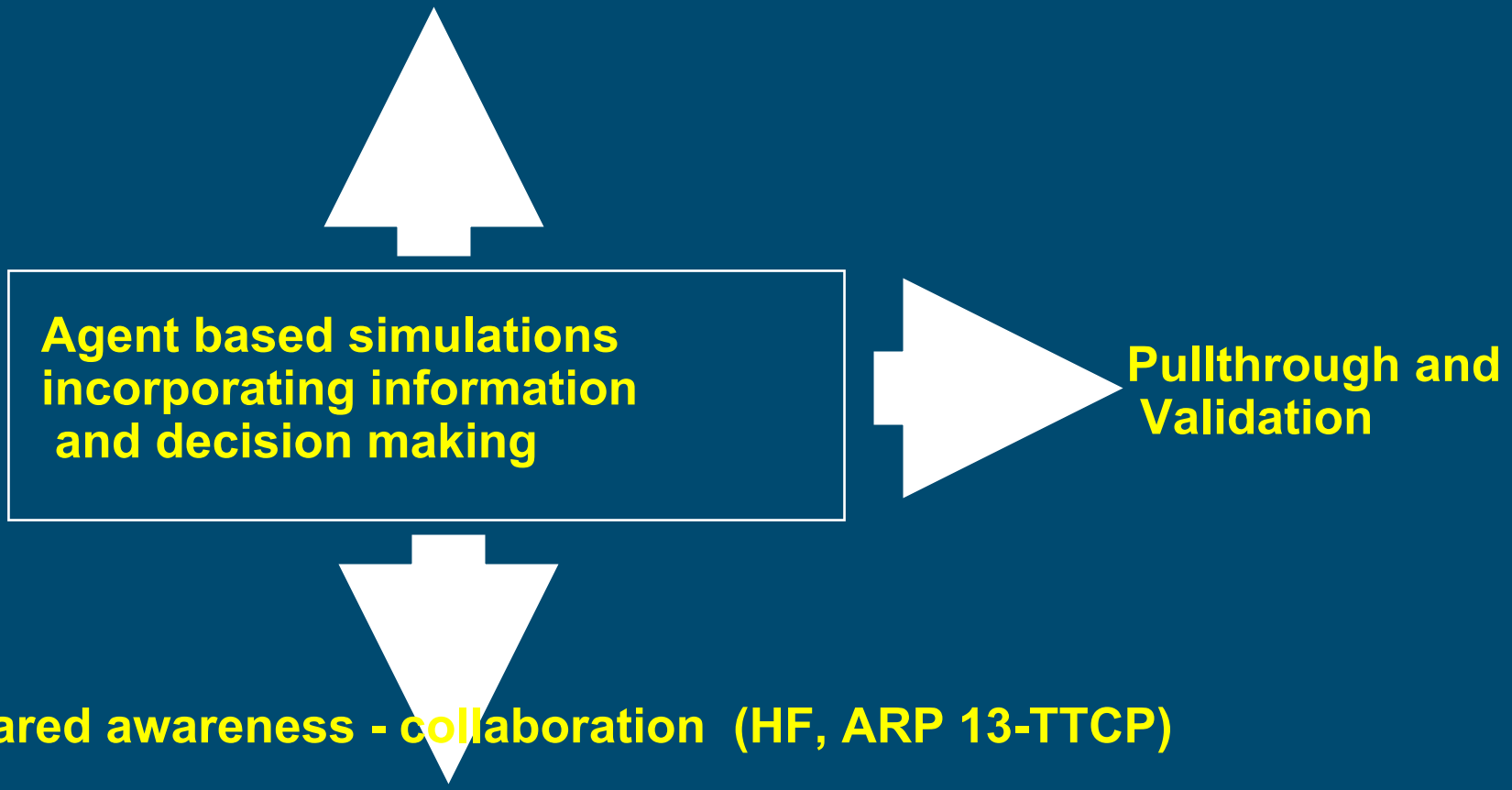
Challenge 1 - quantifying the benefit of good command

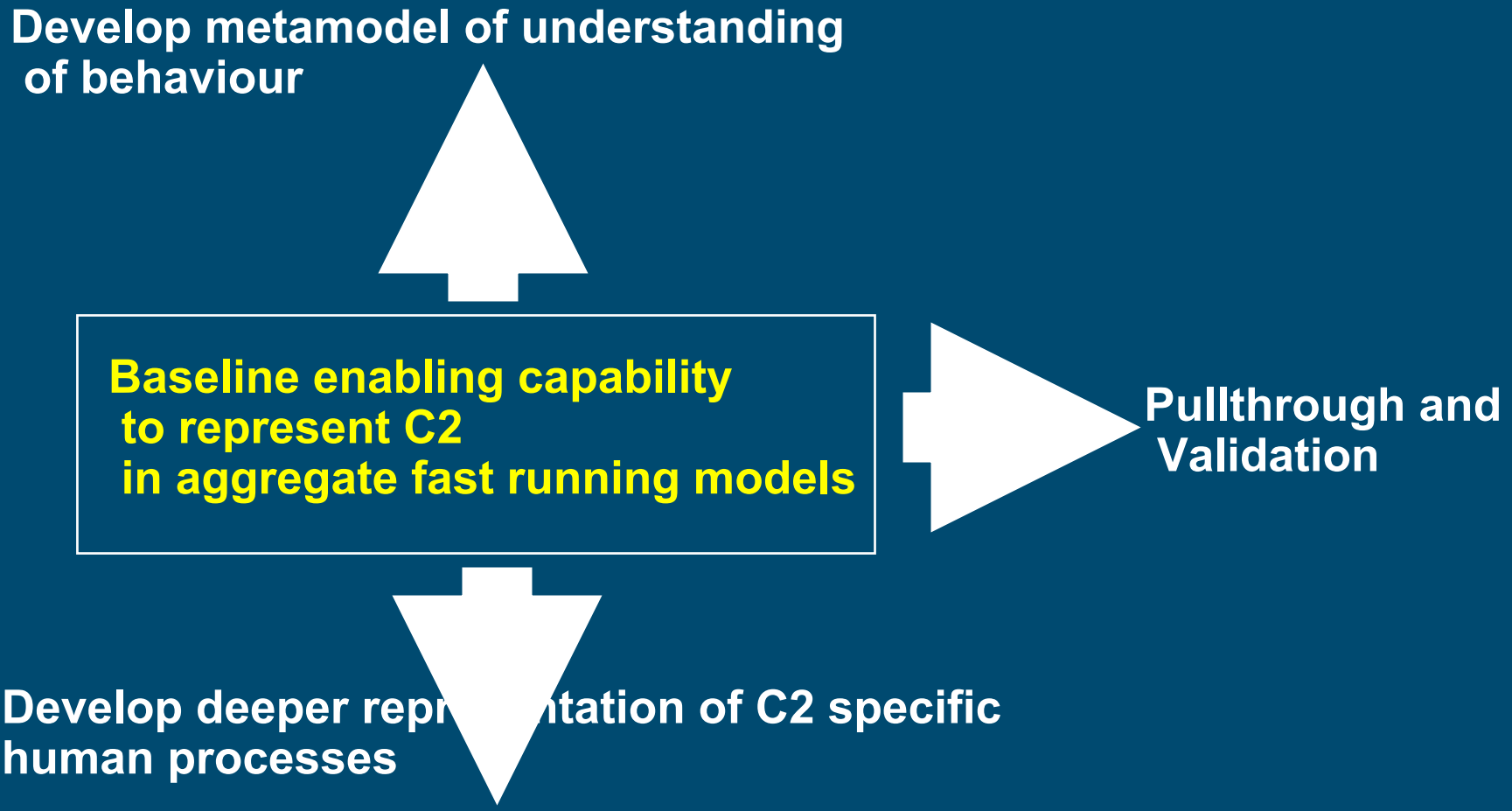
Research Agenda



Network Enabled Capability (NEC) Implications

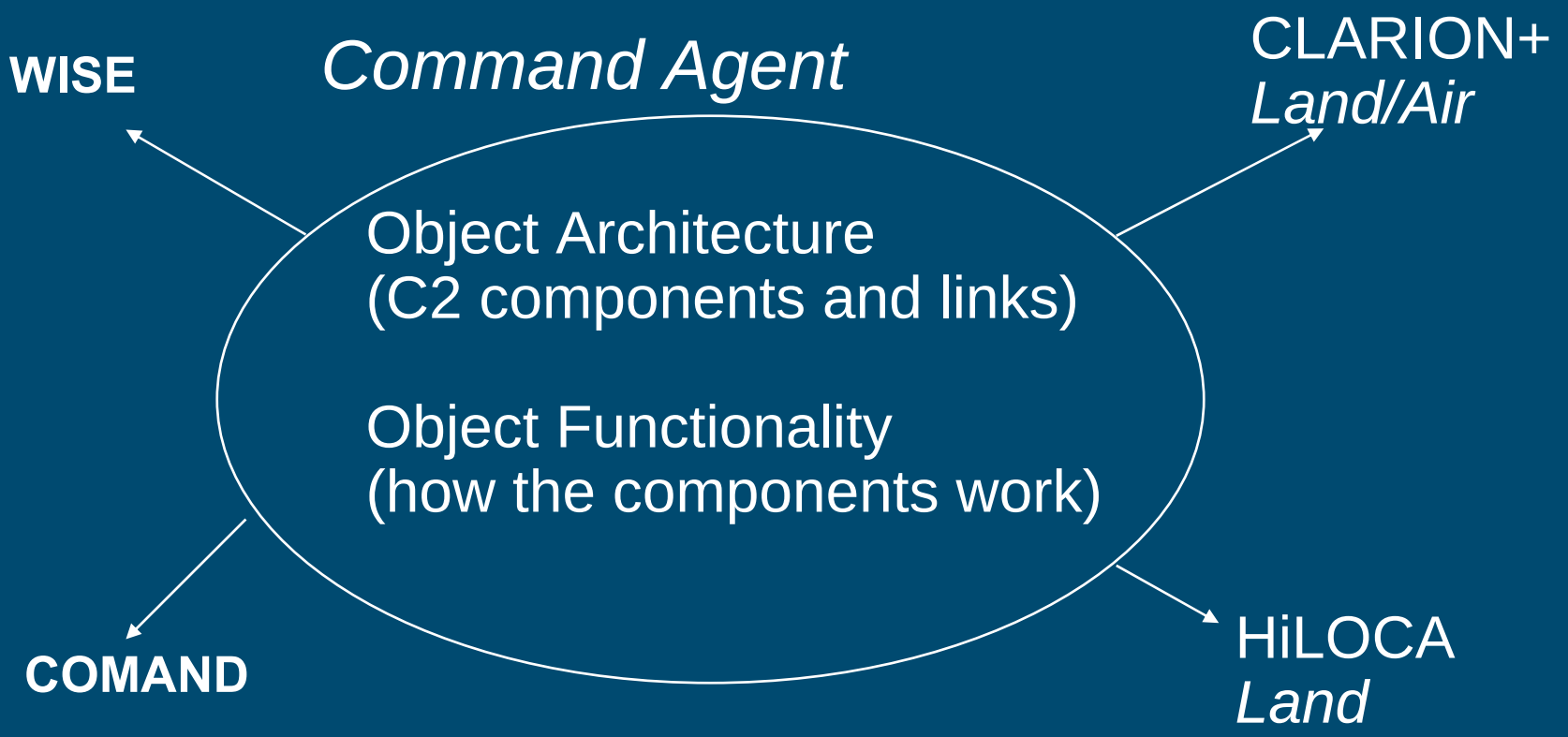
Analytic Models for Future loosely coupled structures (e.g NEC)



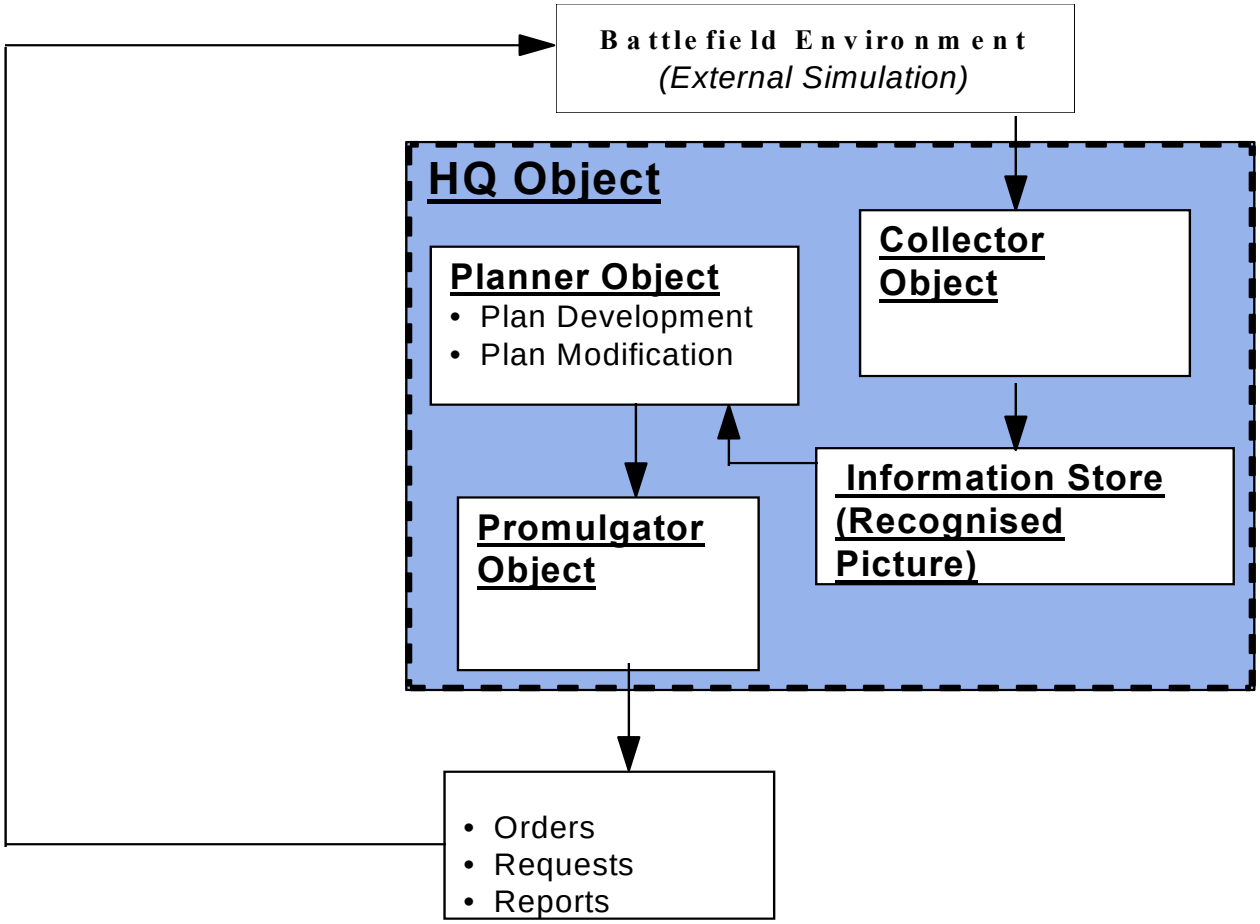

Develop metamodel of understanding of behaviour
Baseline enabling capability to represent C2 in aggregate fast running models
Pullthrough and Validation
Develop deeper repr ntation of C2 specific human processes

Research Principles

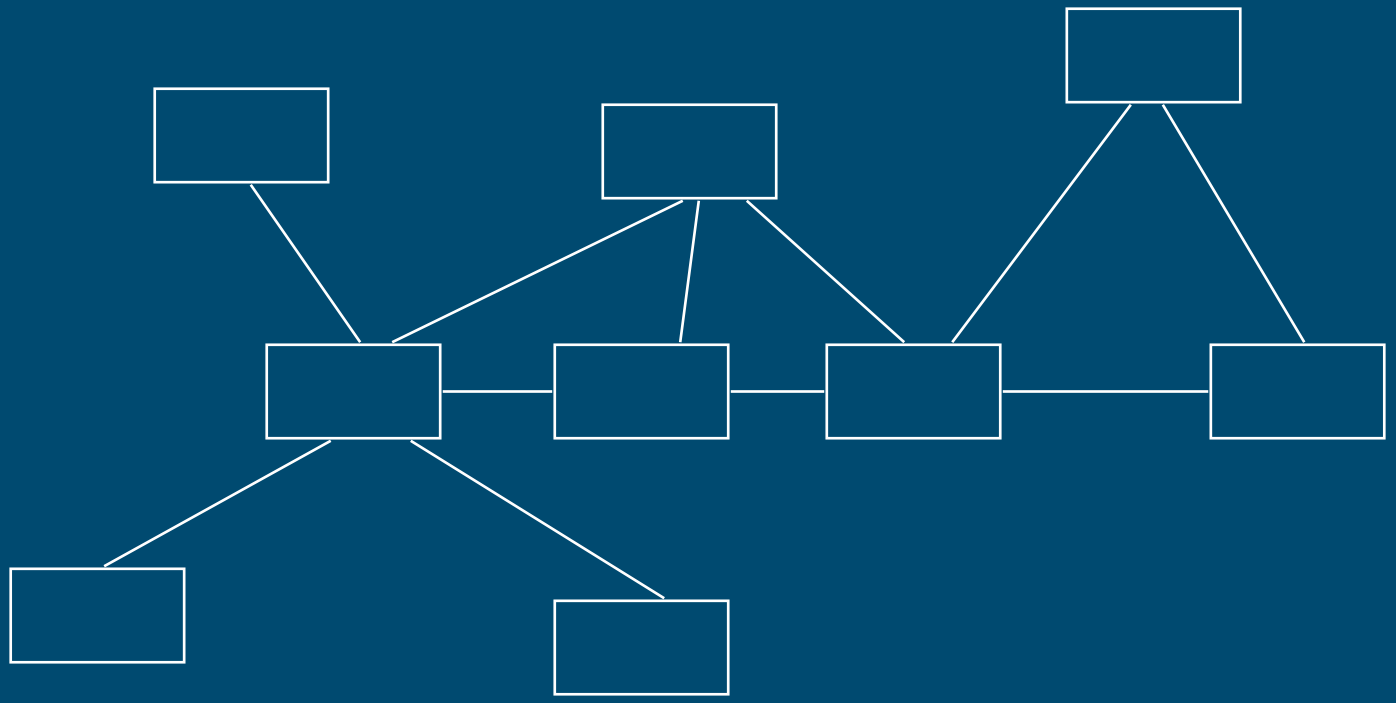
- evolutionary development
- frequent progress demonstrations
- model components complete (holistic)
- **agile, very fast running models**


WISE
Command Agent
CLARION+
Land/Air
Object Architecture
(C2 components and links)
Object Functionality
(how the components work)
COMAND
HiLOCA
Land

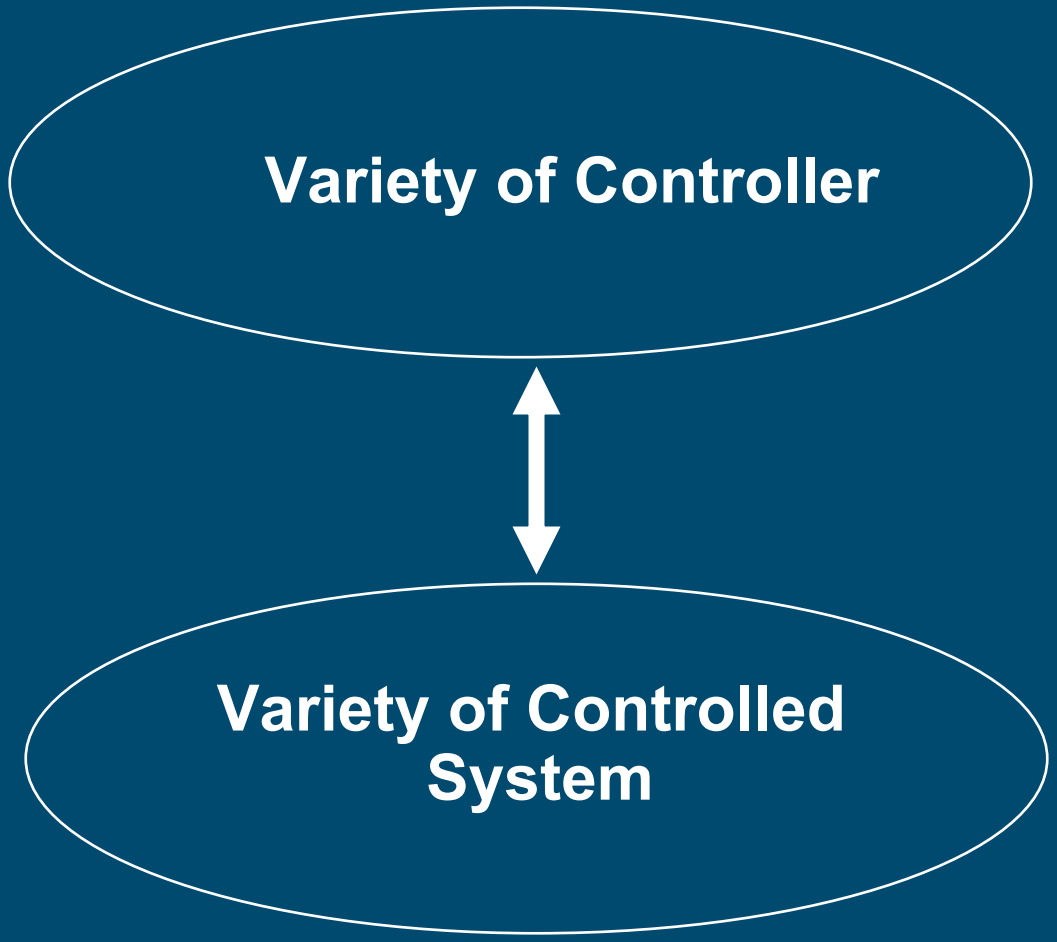
Command Agent



C2 is a network of Generic HQs/Command Agents

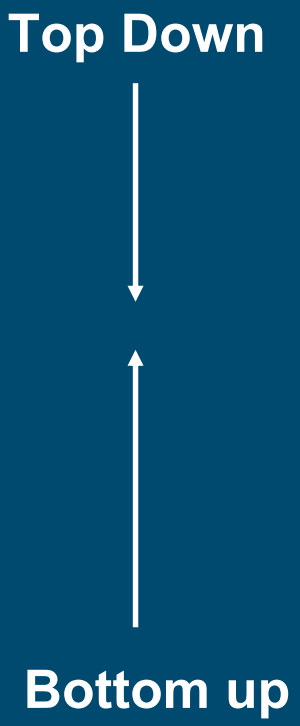


Ashby's Law of Requisite Variety



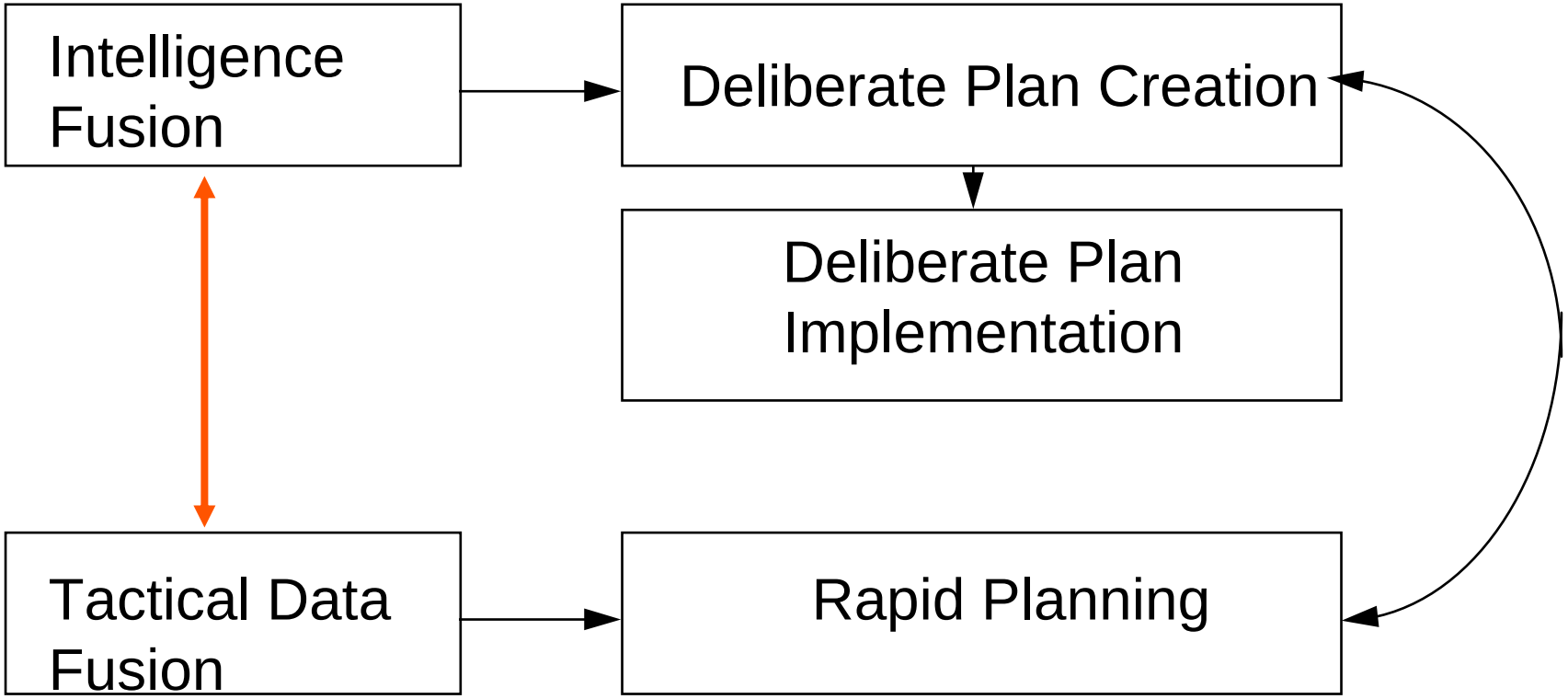
Possible C2 ‘Styles’ (Alberts and Hayes)

- Order Specific
  - Soviet Union
  - Chinese army
- Objective specific
  - UK/US
- Mission specific
  - WW2 Germany
  - Israeli army



Deliberate Planning
'High Command'
top down planning (Formal Estimate)

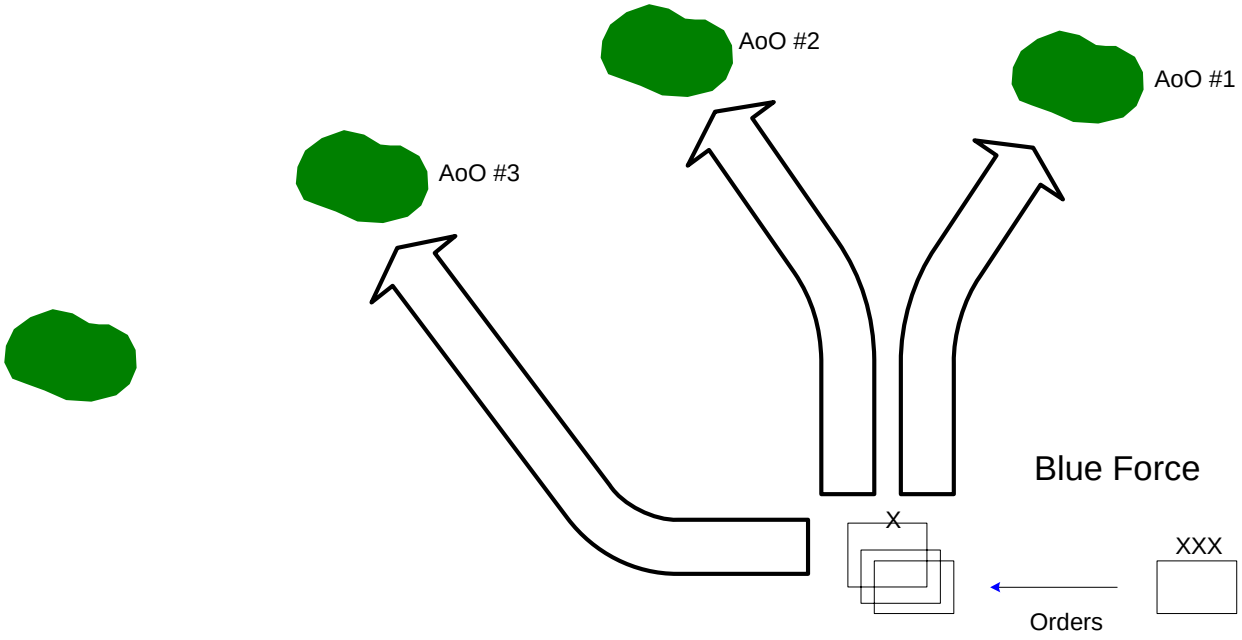
Rapid Planning
'Battle Command'
(Combat Estimate)
creates cybernetic variety/complexity

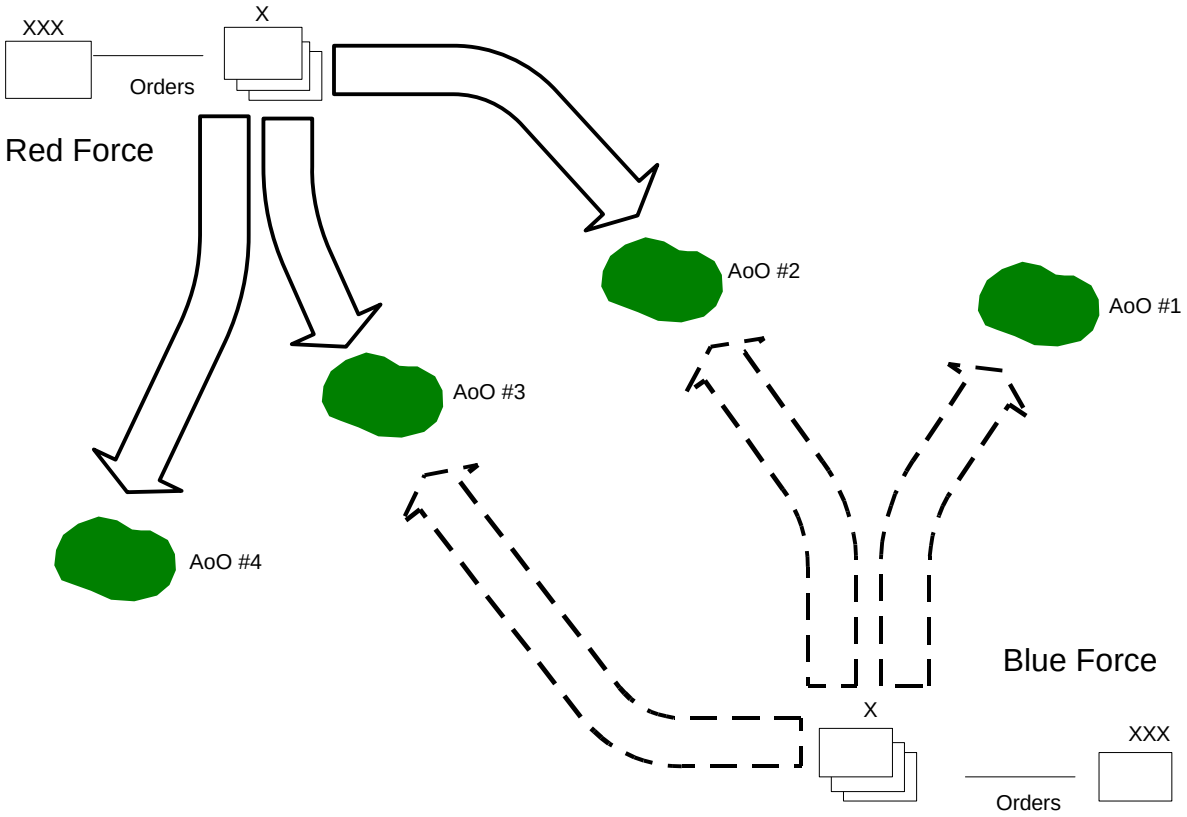

Intelligence Fusion
Deliberate Plan Creation
Deliberate Plan Implementation
Tactical Data Fusion
Rapid Planning

Deliberate Planning

- New scenarios currently require extensive wargame analysis to represent this level of C2
- The aim is to let the model
  - create the overall plan
  - lay out the forces
  - prosecute the plan automatically

IPB Process/ Mobility Corridors/Objectives



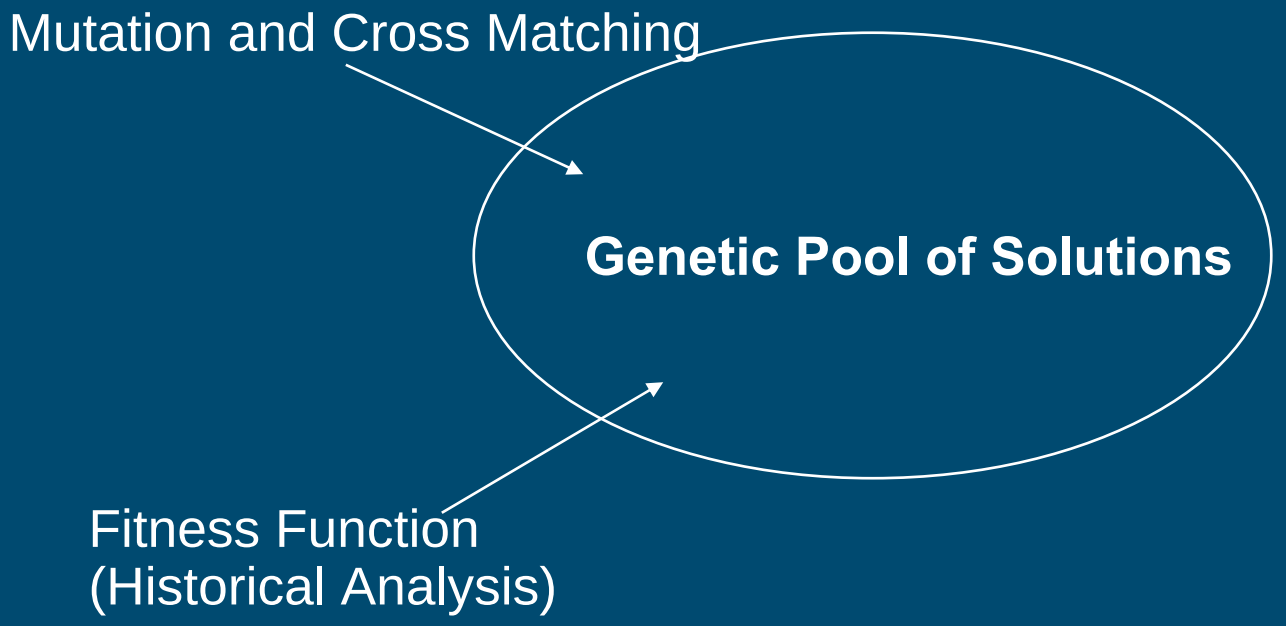

XXX
X
Orders
Red Force
AoO #2
AoO #1
AoO #3
AoO #4
Blue Force
X
XXX
Orders

‘Wargaming’ of Options

	E_1	E_2	...	E_N
O_1	P_{11}	P_{12}	...	P_{1N}
O_2	P_{21}	P_{22}	...	P_{2N}
:	:	:	:	:
O_M	P_{M1}	P_{M2}	...	P_{MN}

- **Allows representation of both Bold and Cautious command**

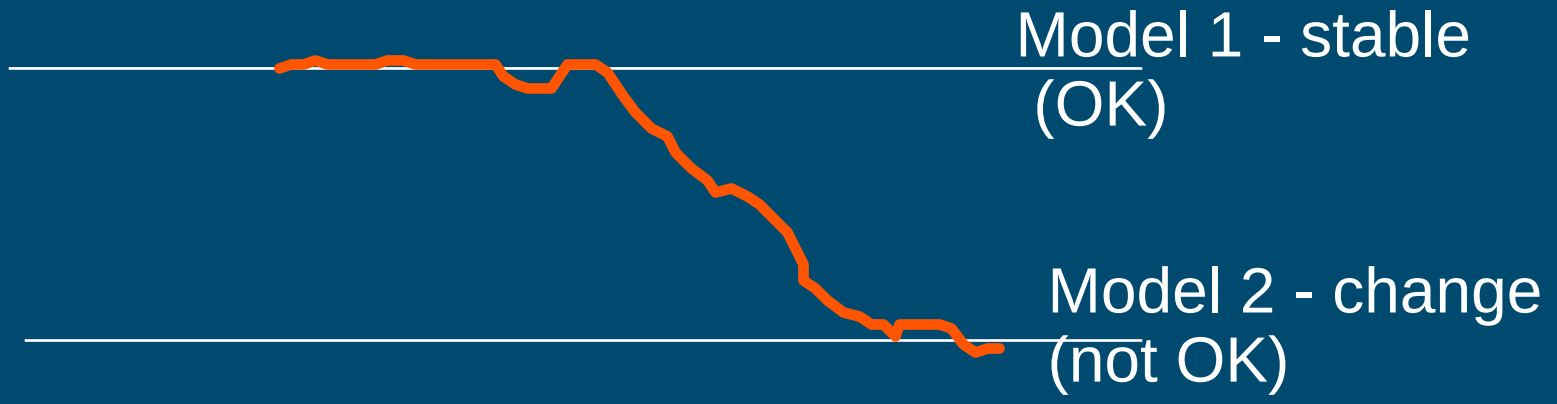
Innovative Deliberate Planning - Genetic Algorithm



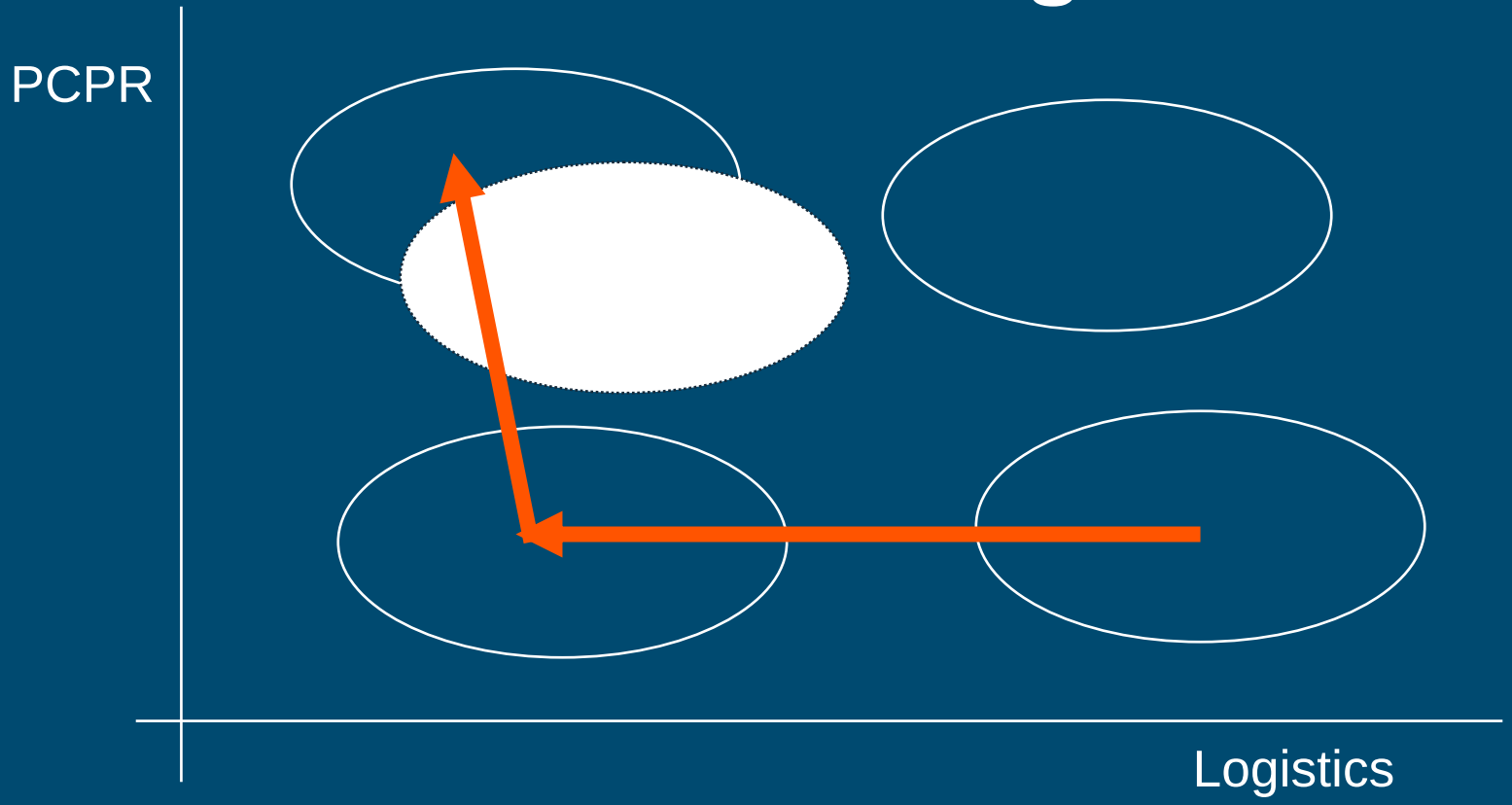
Rapid Planning (Combat Estimate) some key human features

- Mission based
- Effect of stress
- Based on own perception and local circumstance
- Intuitive in nature
- Desired mission might be a ‘fuzzy’ construct

Dynamic Linear Model- *Story Telling - have things changed?*



Situation Assessment- Klein Pattern Matching/RPDM



Key Dstl models entering study programme

COMAND

joint campaign level

warfighting

DIAMOND

joint campaign level

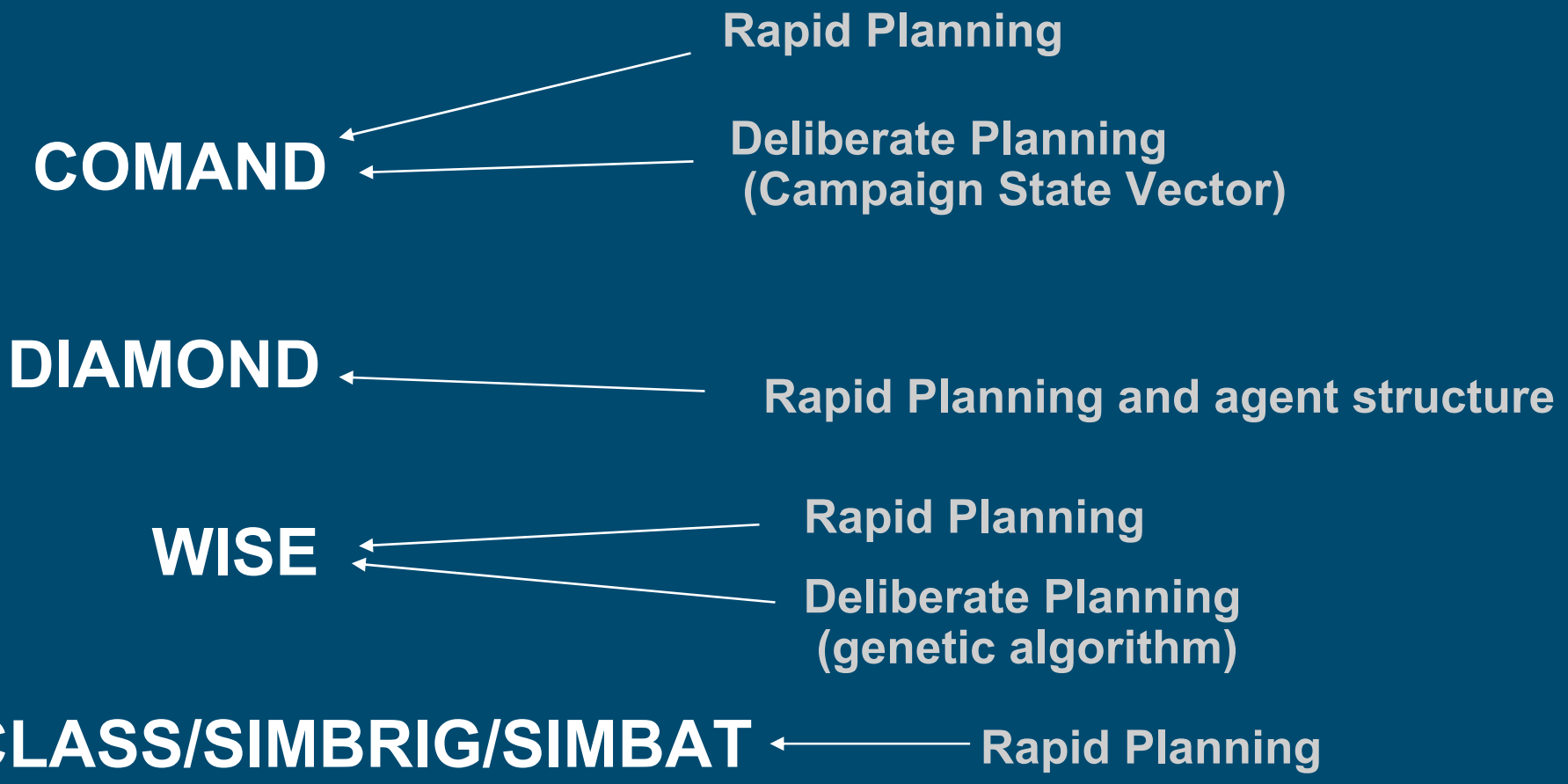
peacekeeping

WISE

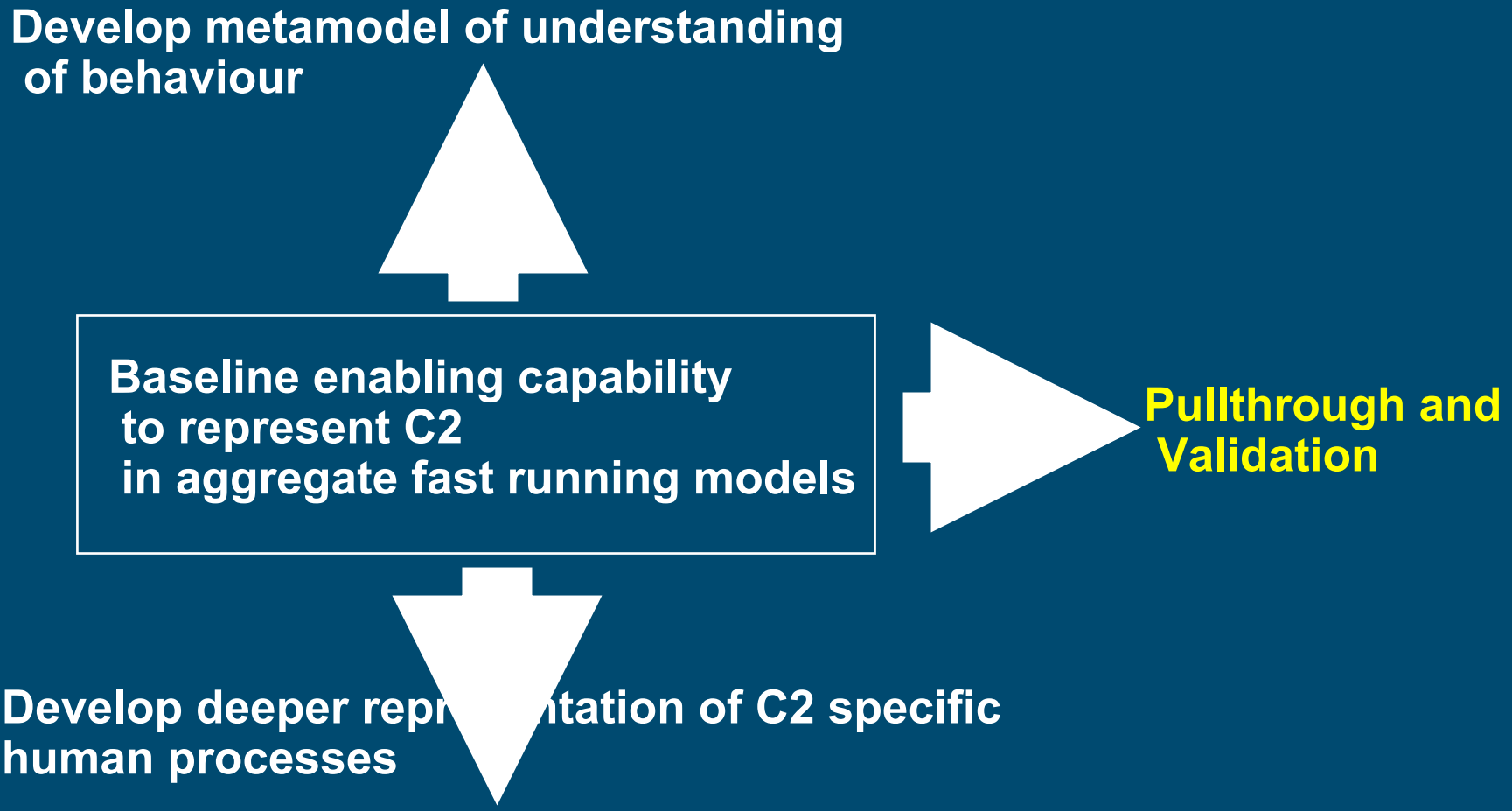
Land formation level game/simulation

warfighting/peacekeeping

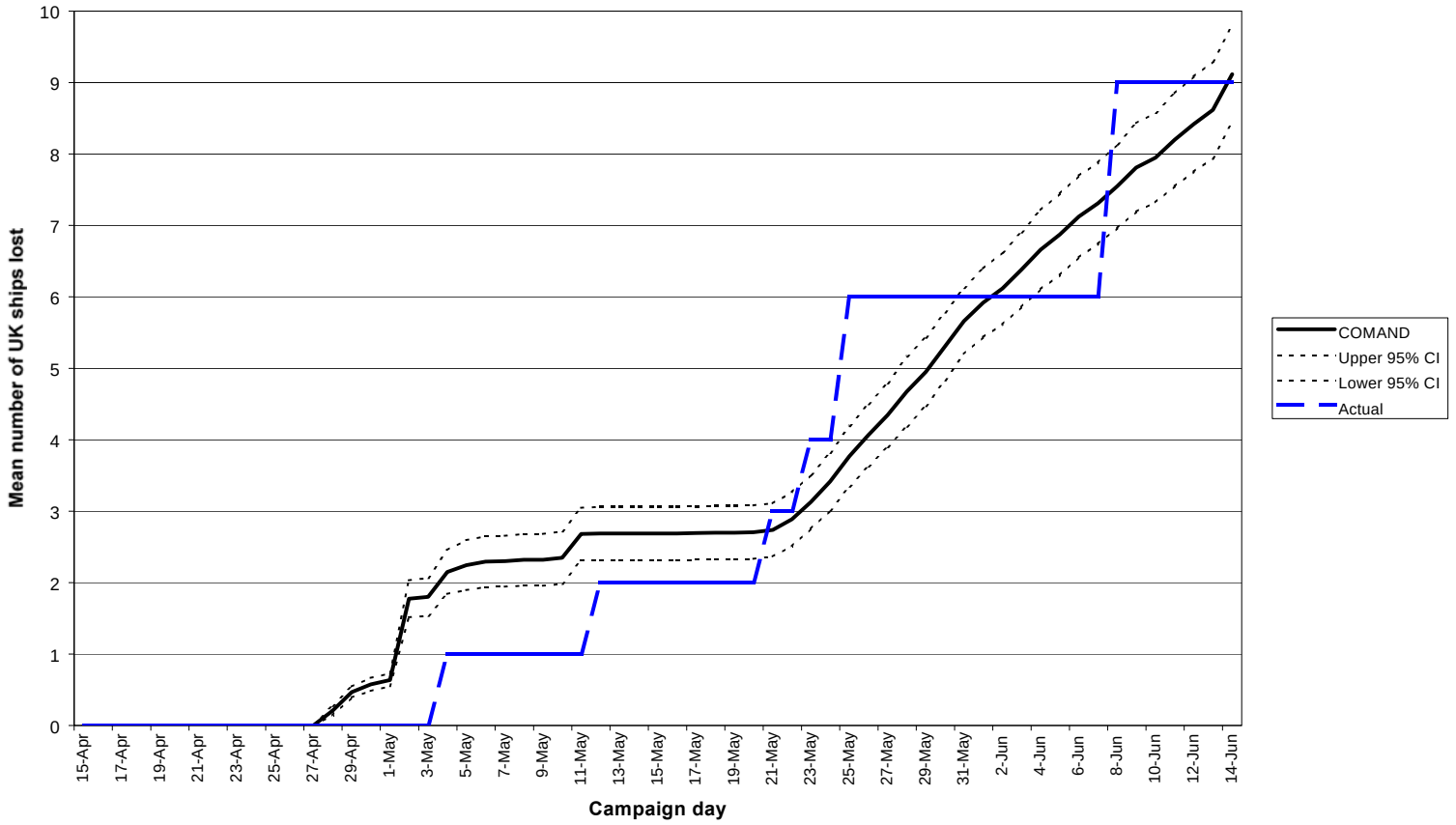
All these models are C2 centred, based on our approach to C2 representation



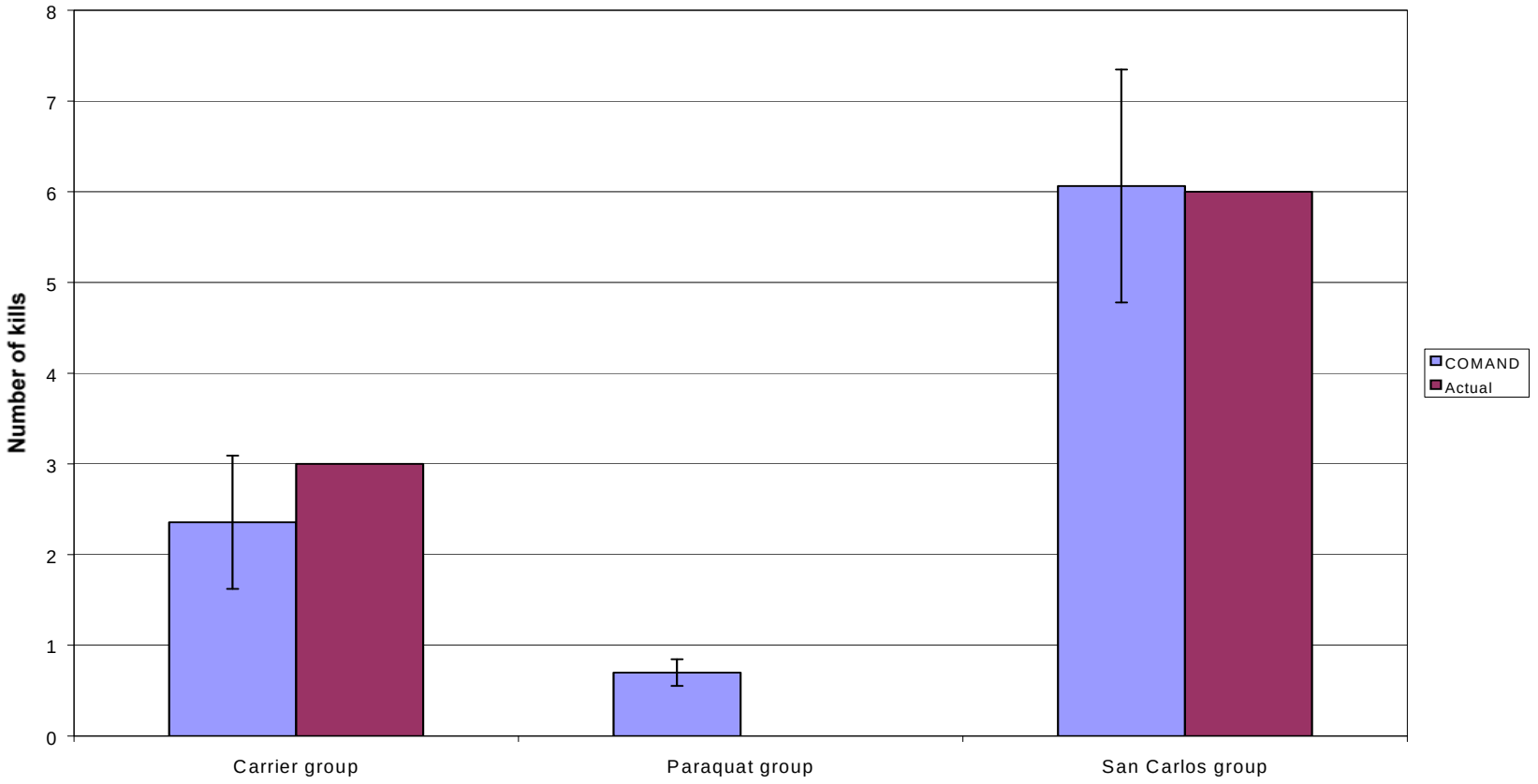
Validation



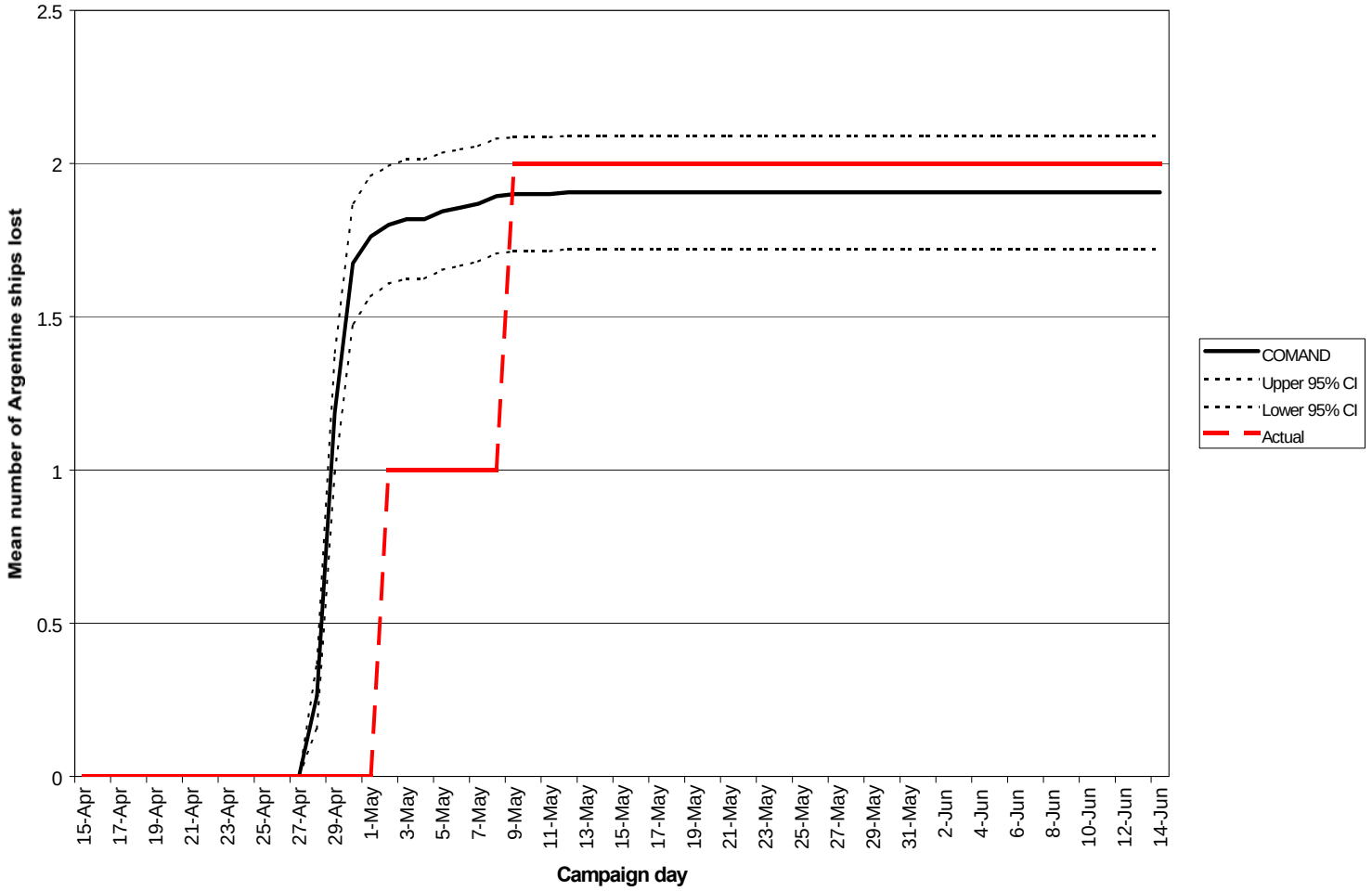
Validation in COMAND - UK ships lost over time



UK losses by type



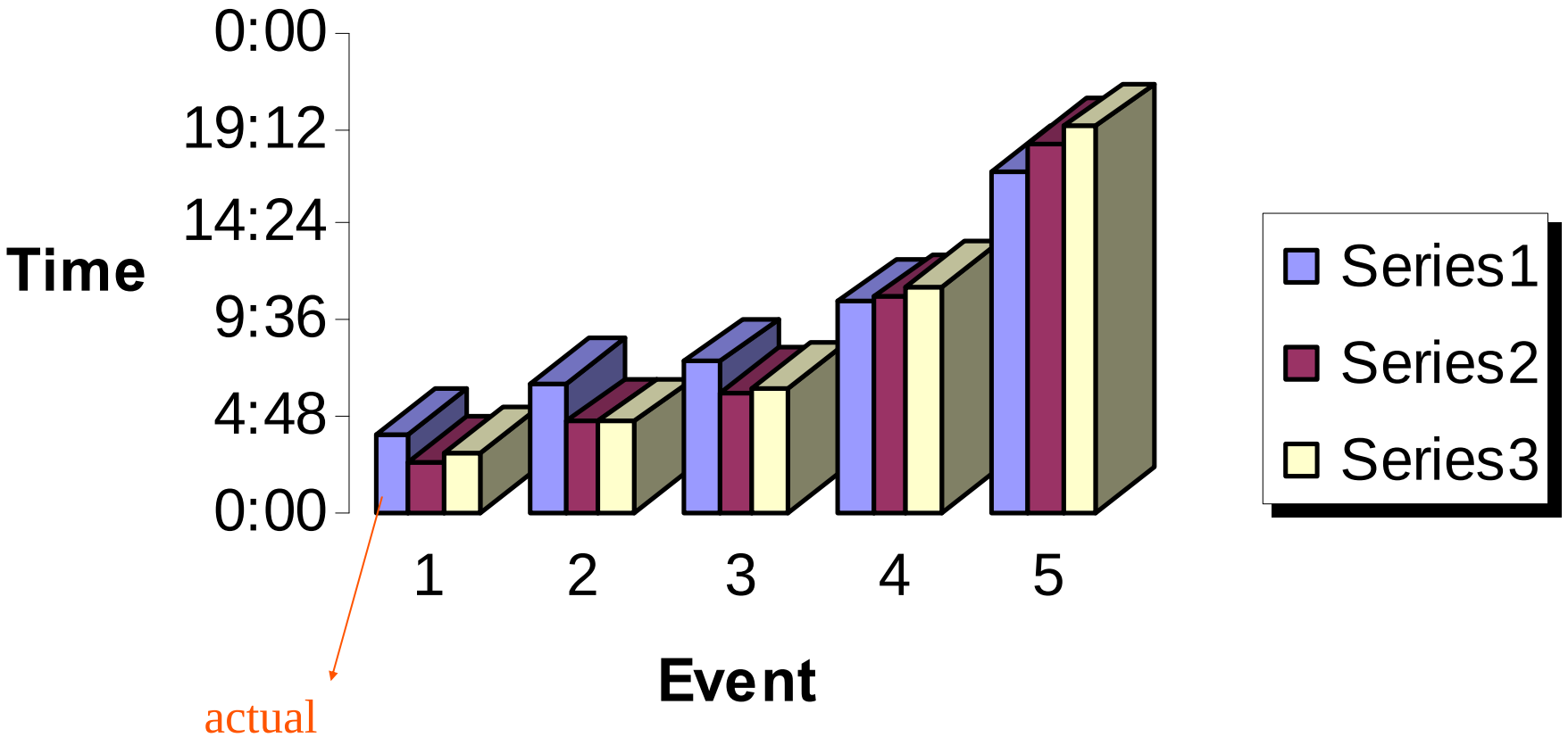
Argentinian ship losses



Validation of SIMBAT

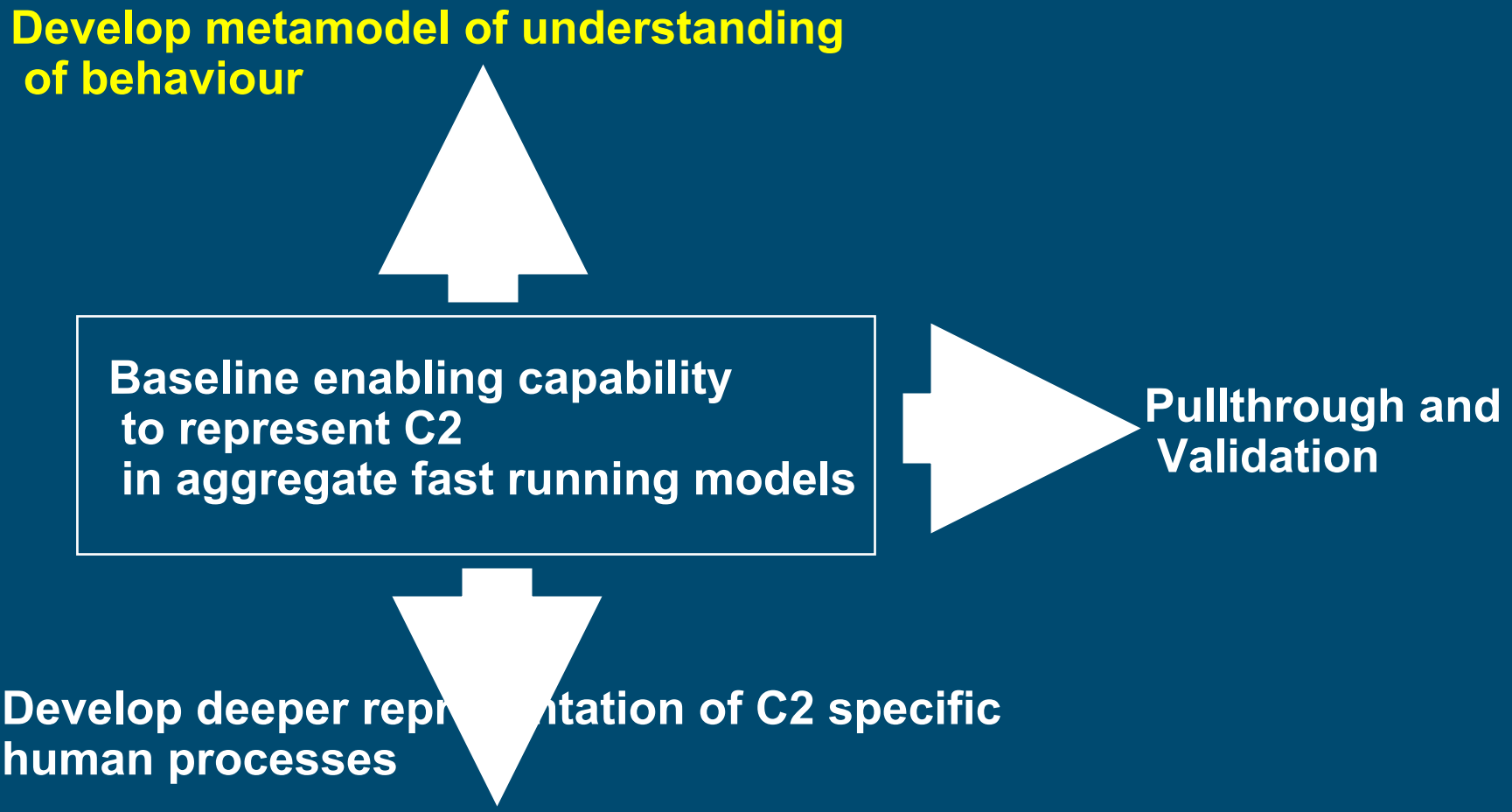
- Battle of Goose Green 1982
- Operation Epsom 1944
- Brigade level operations 1944-45
- Comparison with CAEN
- Comparison with BATUS trials

Goose Green Battle Dynamics

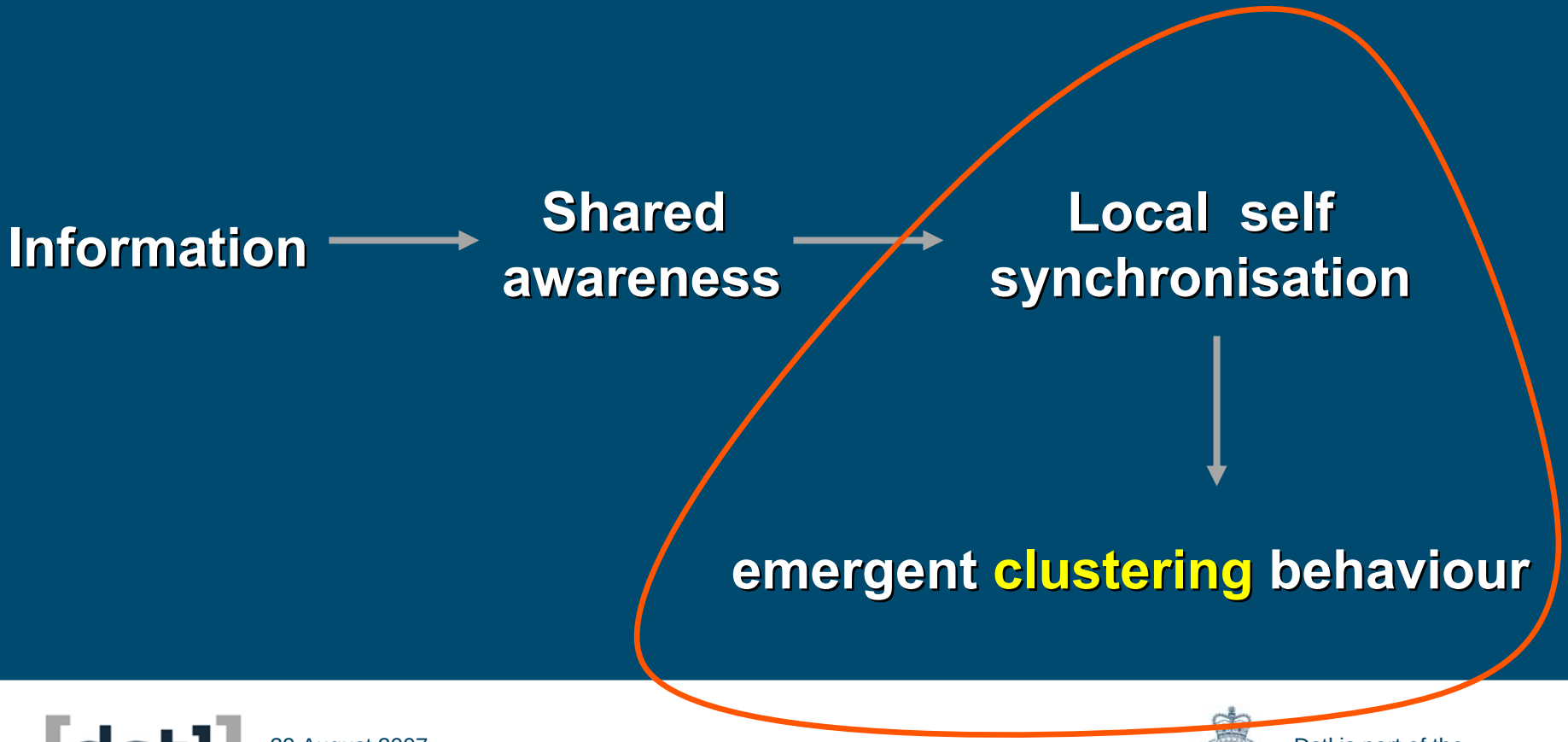


Challenge 2 - understanding emergent behaviour

Research Agenda



network enabled warfare/Information age warfare



Roberts and Turcotte data

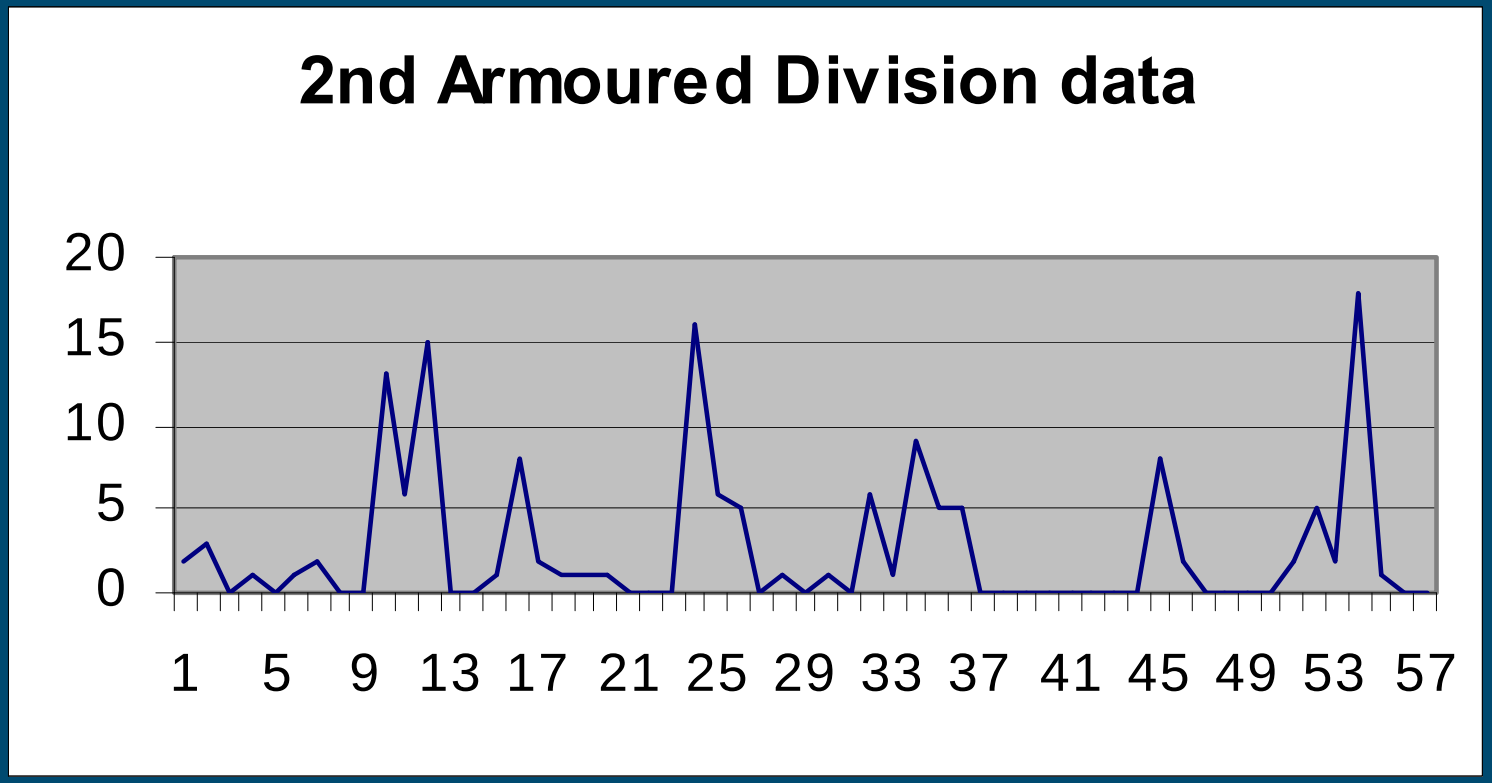
- Real forest fires (4 data sets 4284, 120, 164, 298)

  power law with slope 1.3-1.5

- Real wars (2 data sets: 119, 1495 - 1973; 118, 1816 -

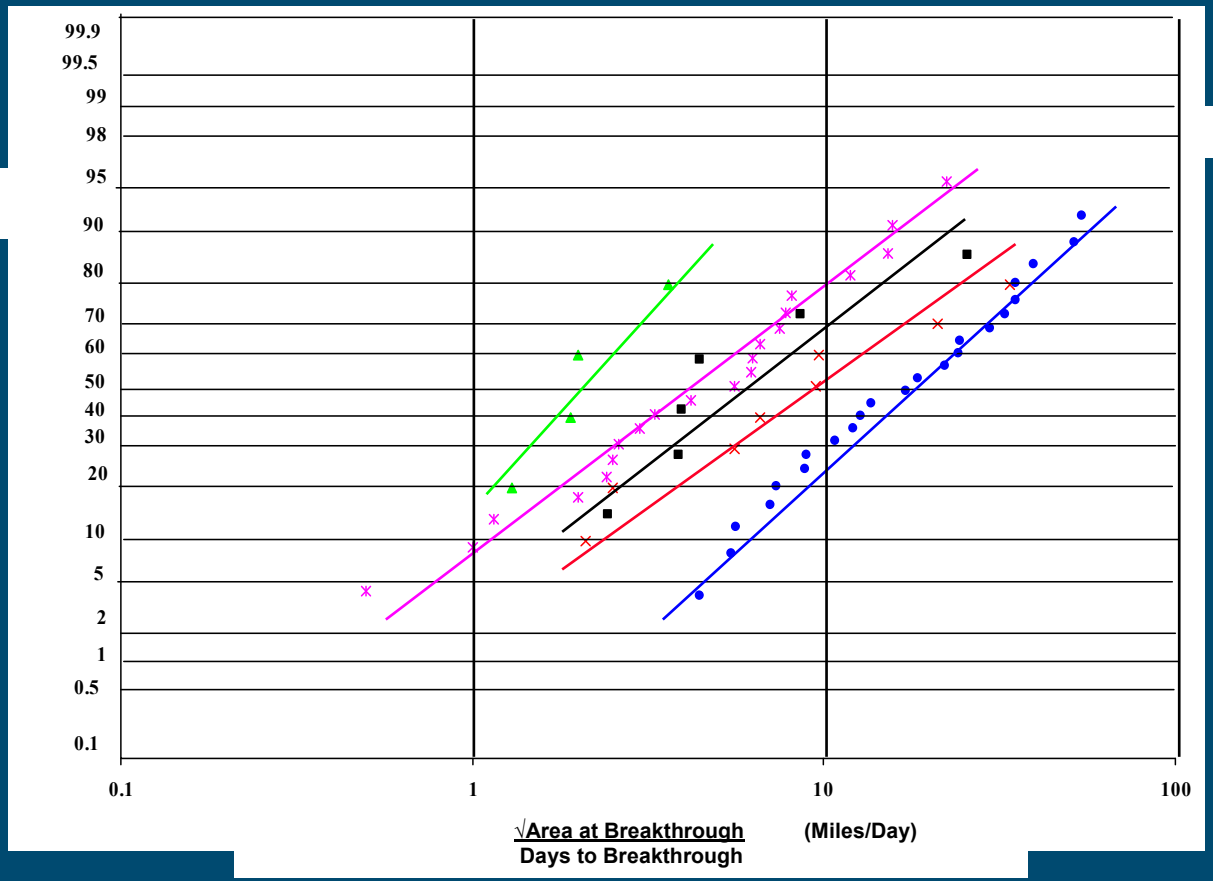
  1980) power law with slope 1.3-1.4

US WW2 data on casualties suffered



Irruption as complex process

Fig 2: Cumulative Distributions of √Area/Duration at Breakthrough



General Form of a Metamodel -similarity parameter b (e.g Fluid Dynamics)

$$a = f(a_1, \ldots, a_k, b_1) = a_1^p \ldots a_k^r \Phi\left(\frac{b_1}{a_1^{p_1} \ldots a_k^{r_1}}\right)$$

Casualties or Control

Unit effectiveness

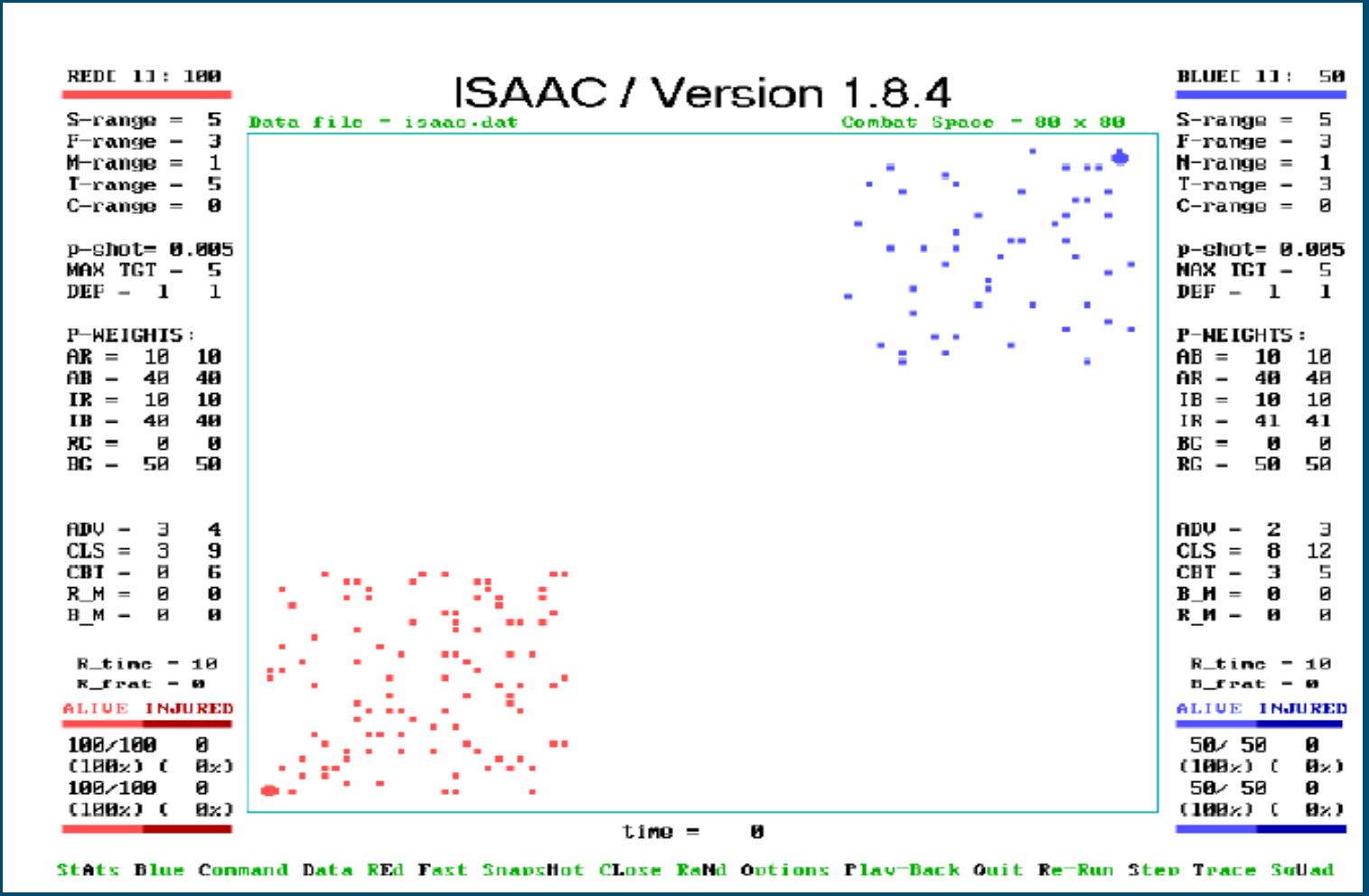
Clustering of forces or effects

Fractal Dimension - ‘Similarity’

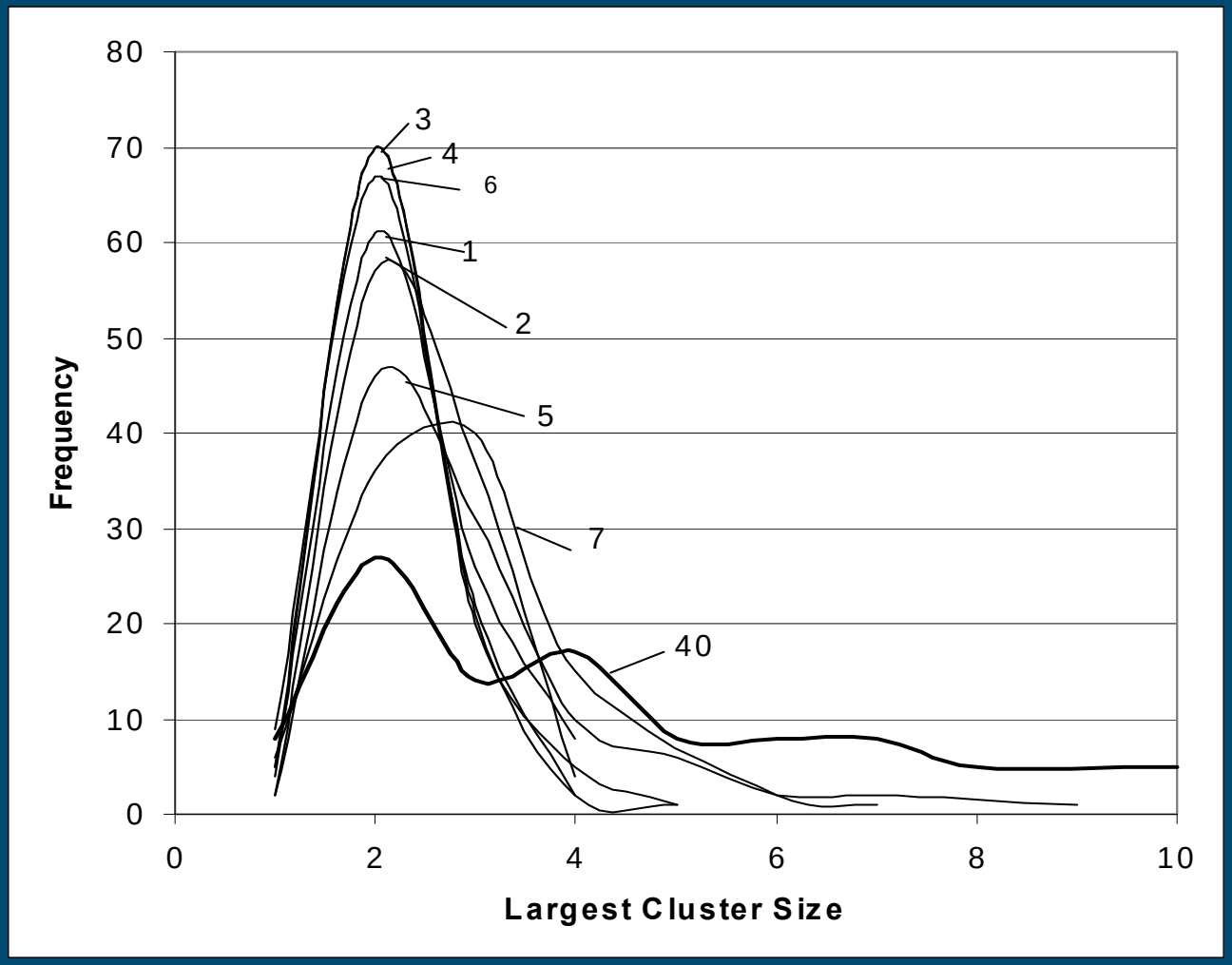
Case (requirement is for Blue to reach 25% casualty level).	Red Fractal Dimension *D*
'Dispersed'	0.7
'Linear'	1.7
Stochastic Lanchester	2
Recce	0.8
'Dispersed'	0.9
'Dynamic'	1.0
'Fluid'	1.1
'Classic Fronts'	1.7

Table 6.1 ISAAC mean fractal dimensions

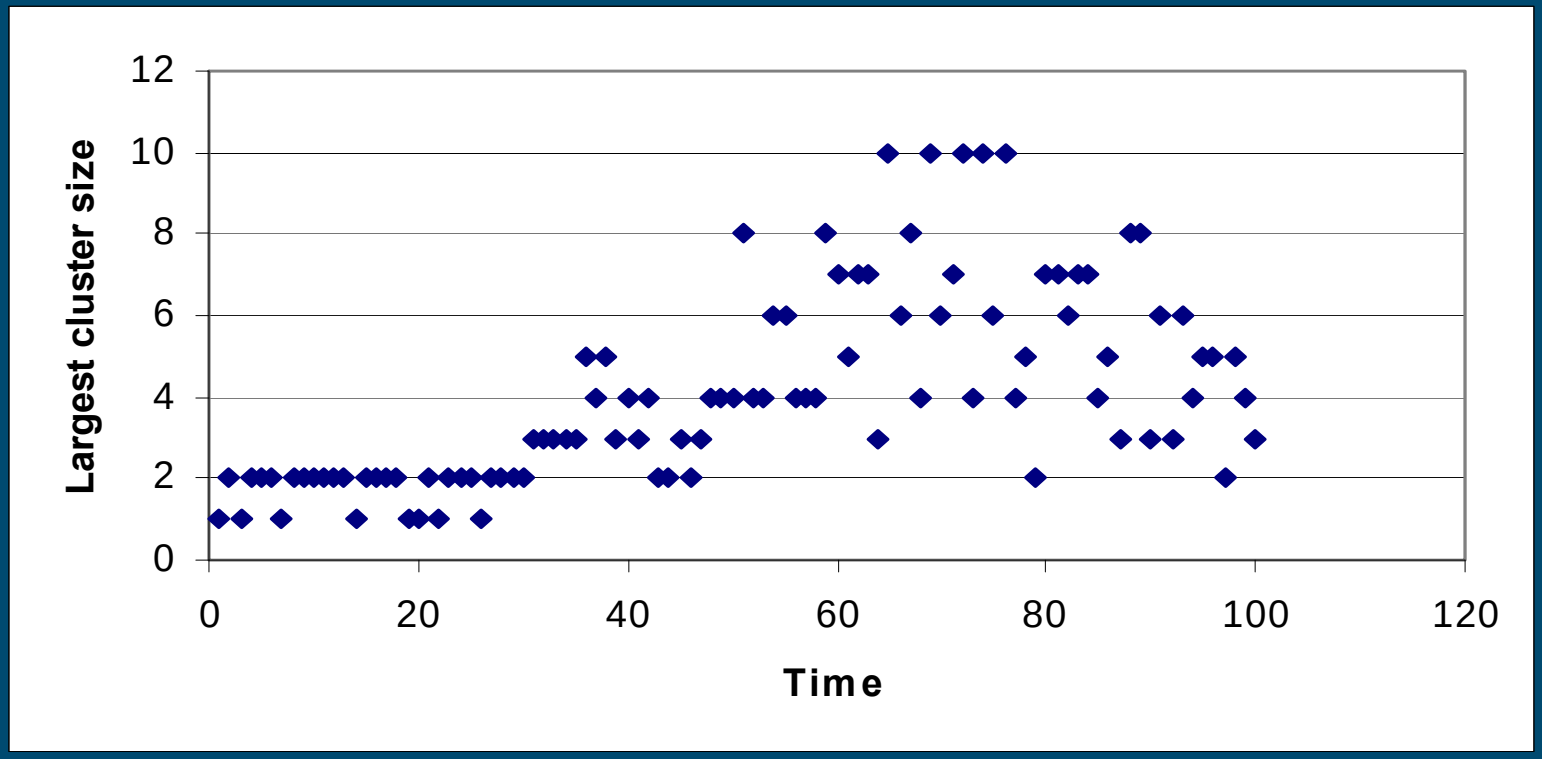
Example of ISAAC start condition



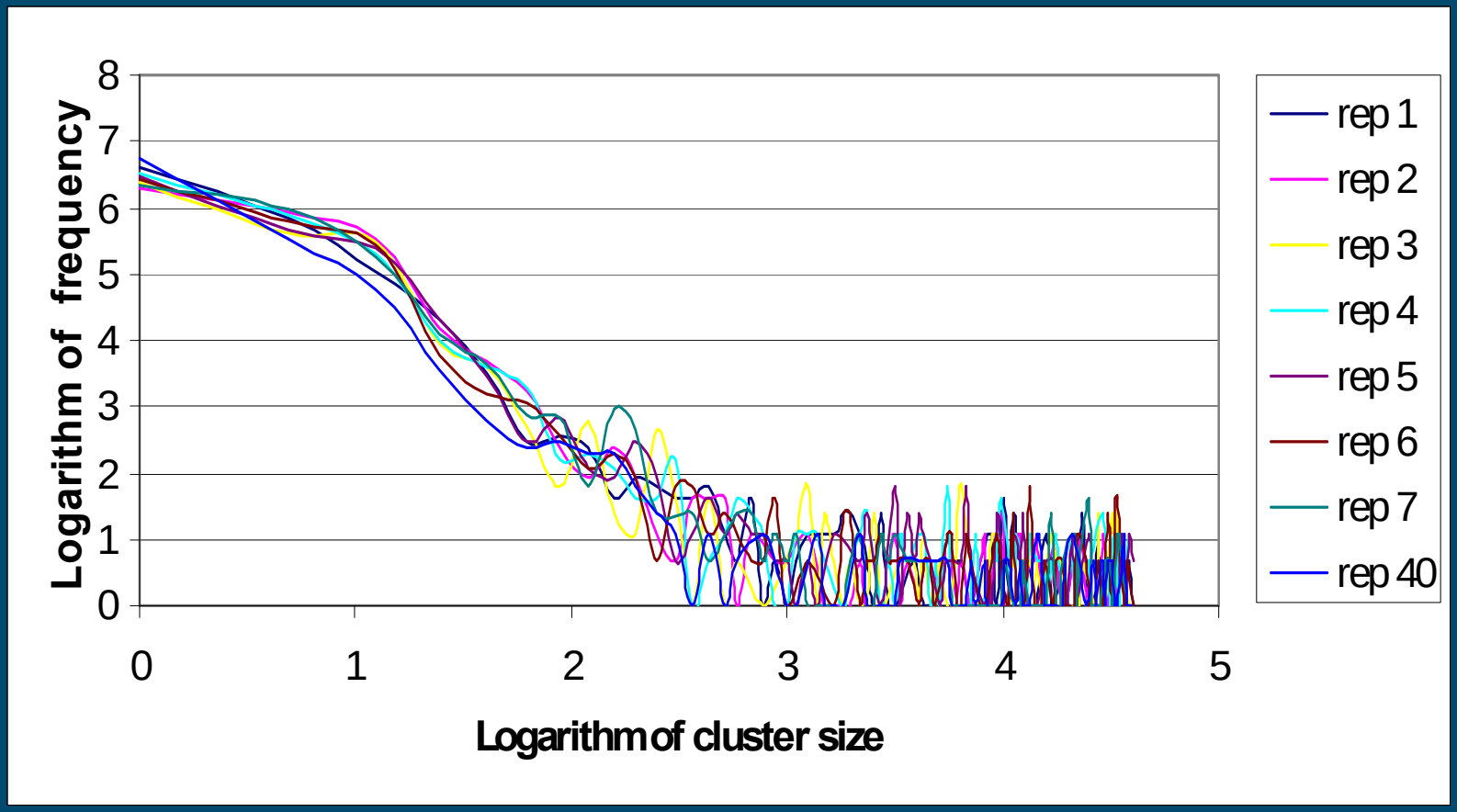
Blue cluster size distribution



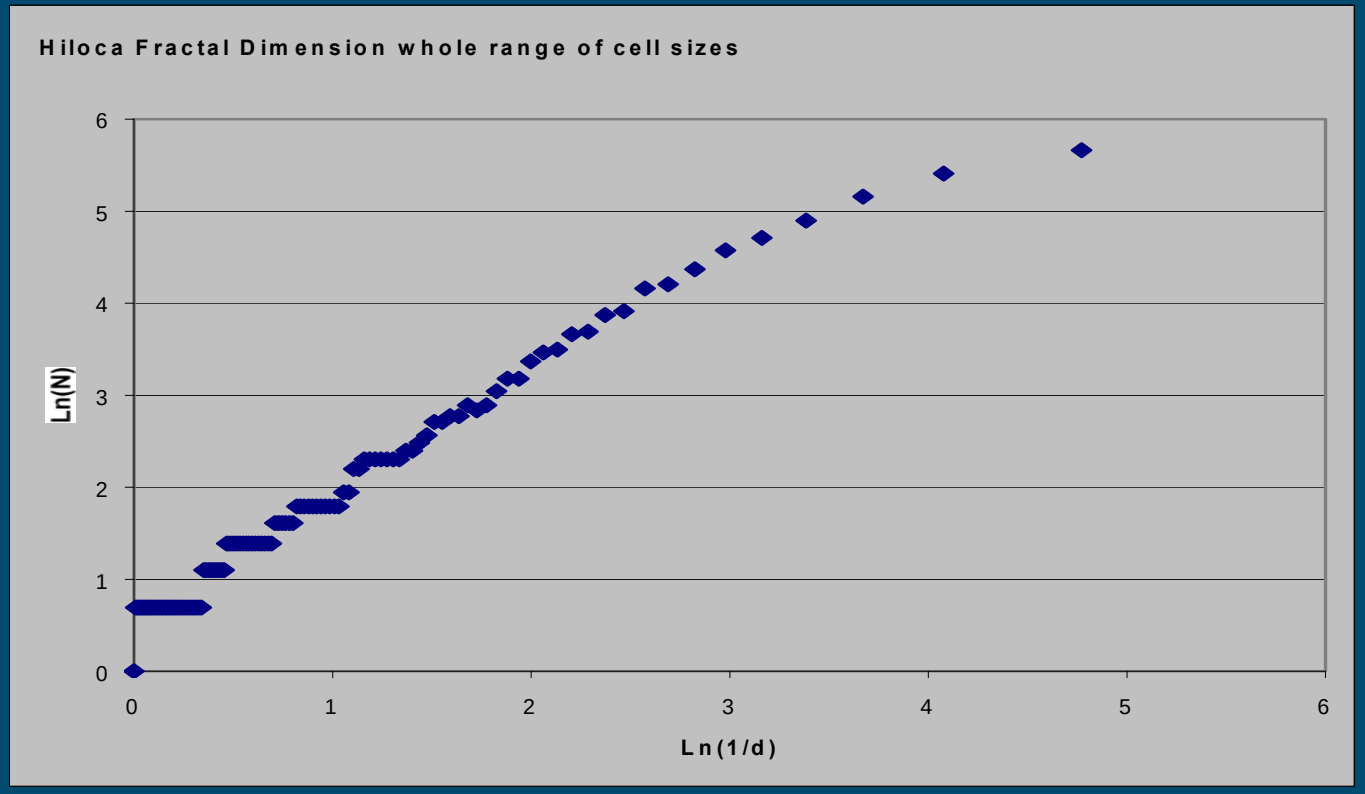
Blue largest cluster size over time



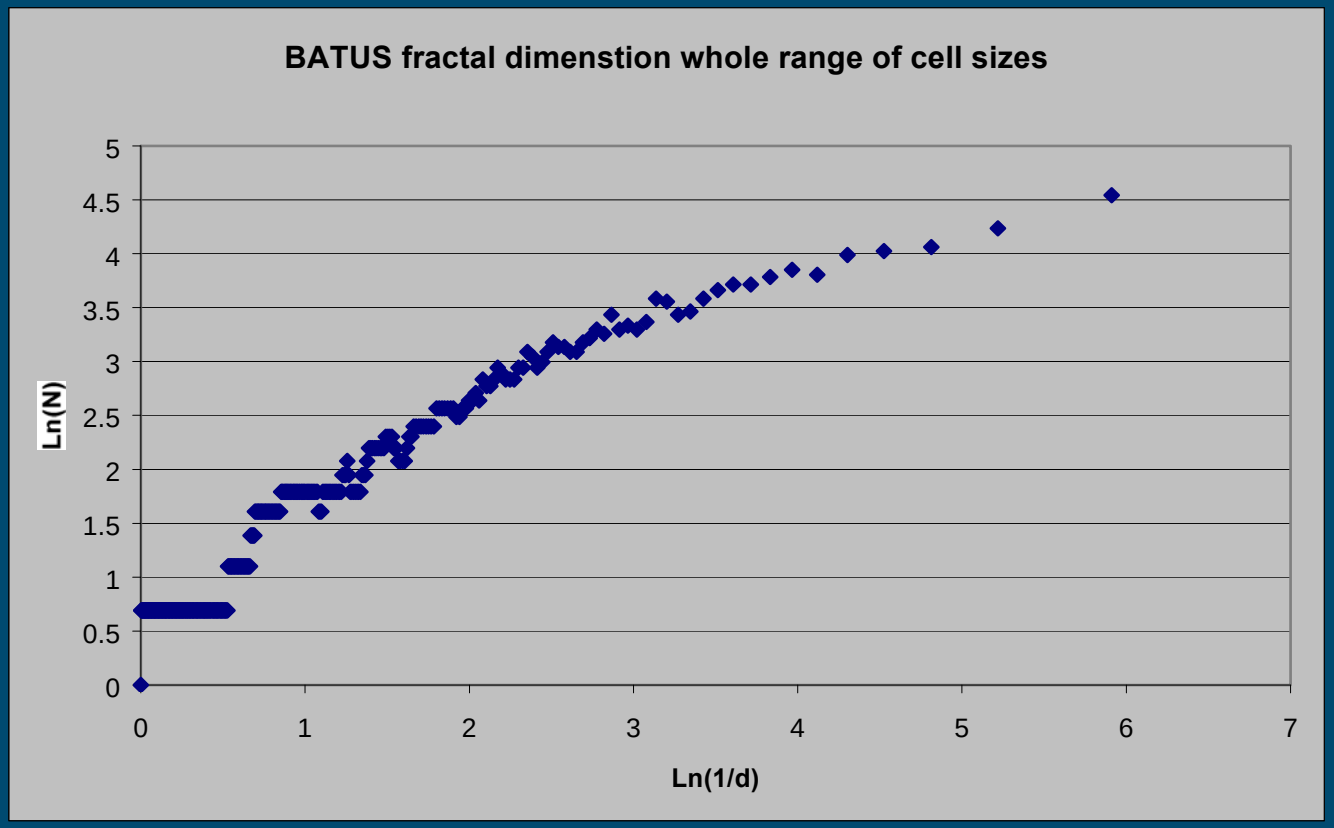
Red distribution of cluster size



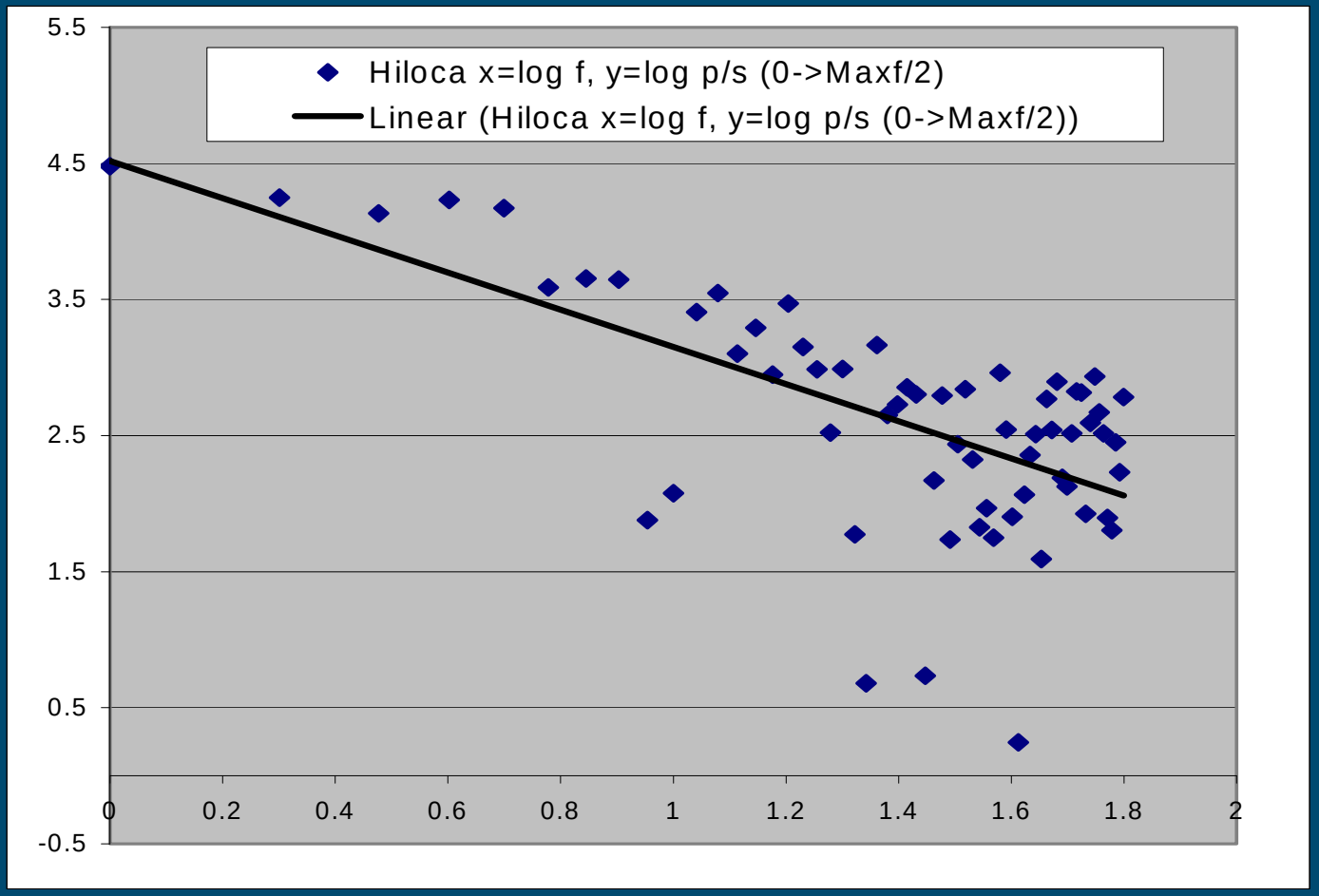
Agent simulation force fractal dimension



BATUS experimental data using GPS locations

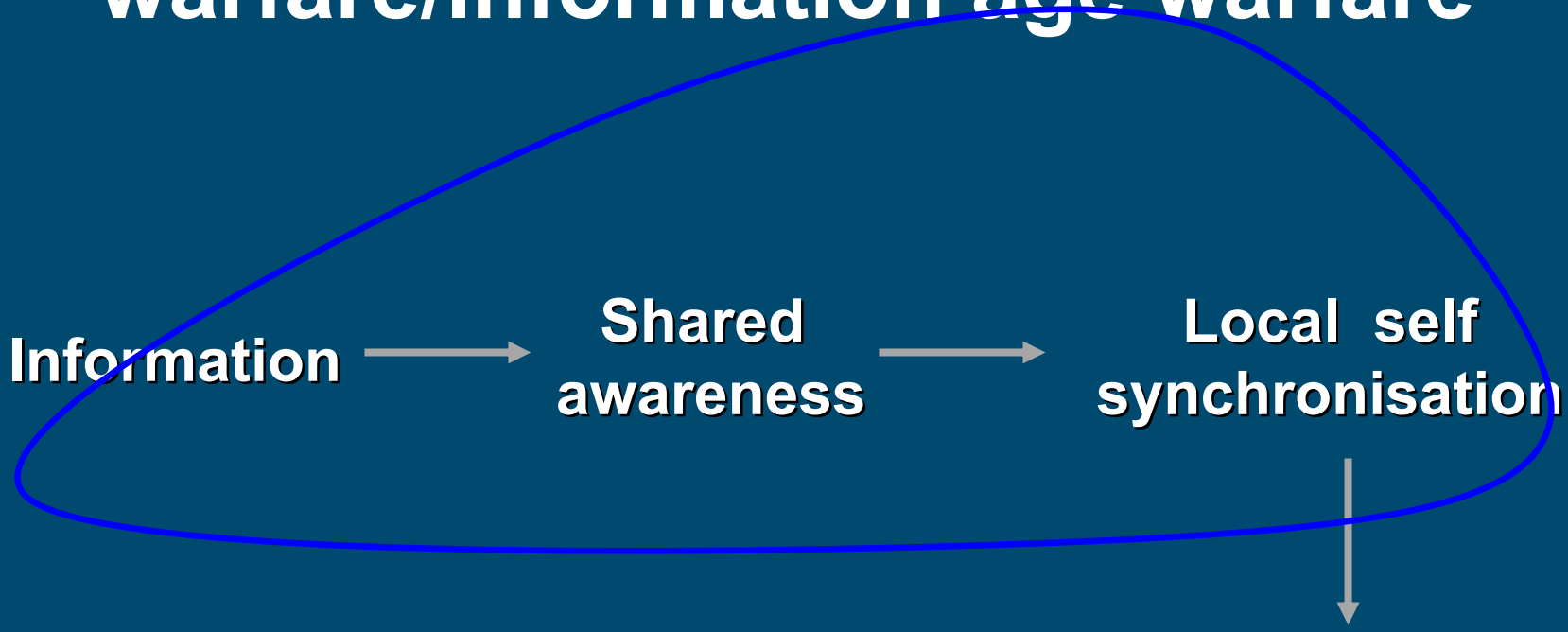


Power spectrum of casualties from agent simulation

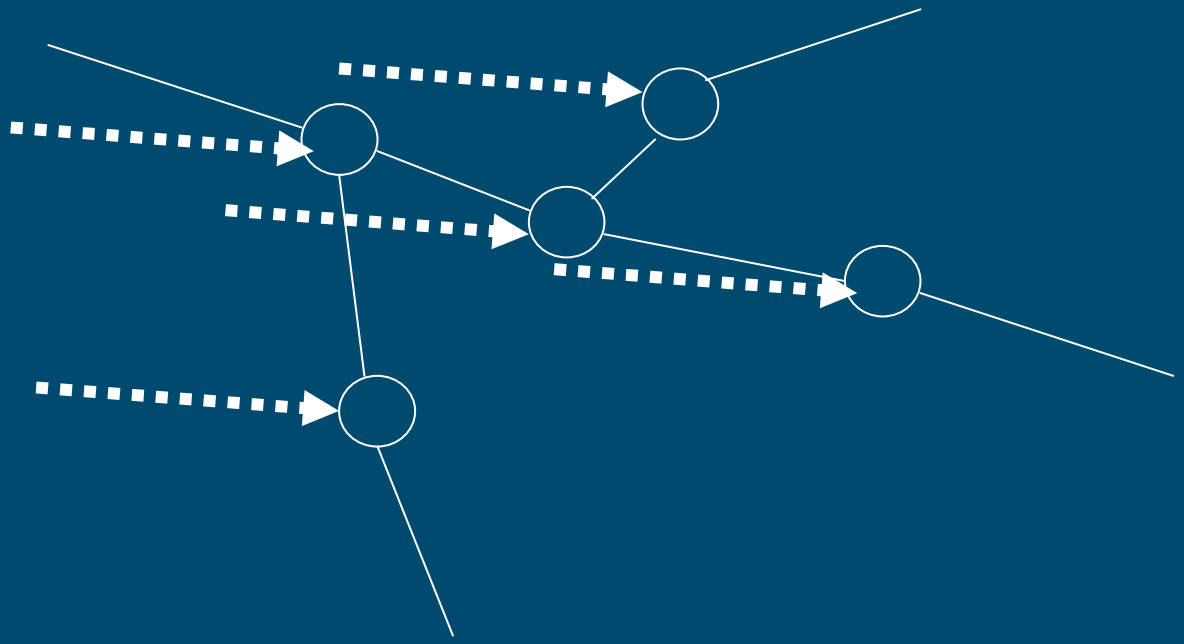


Challenge 3 - modelling clustering across an information network

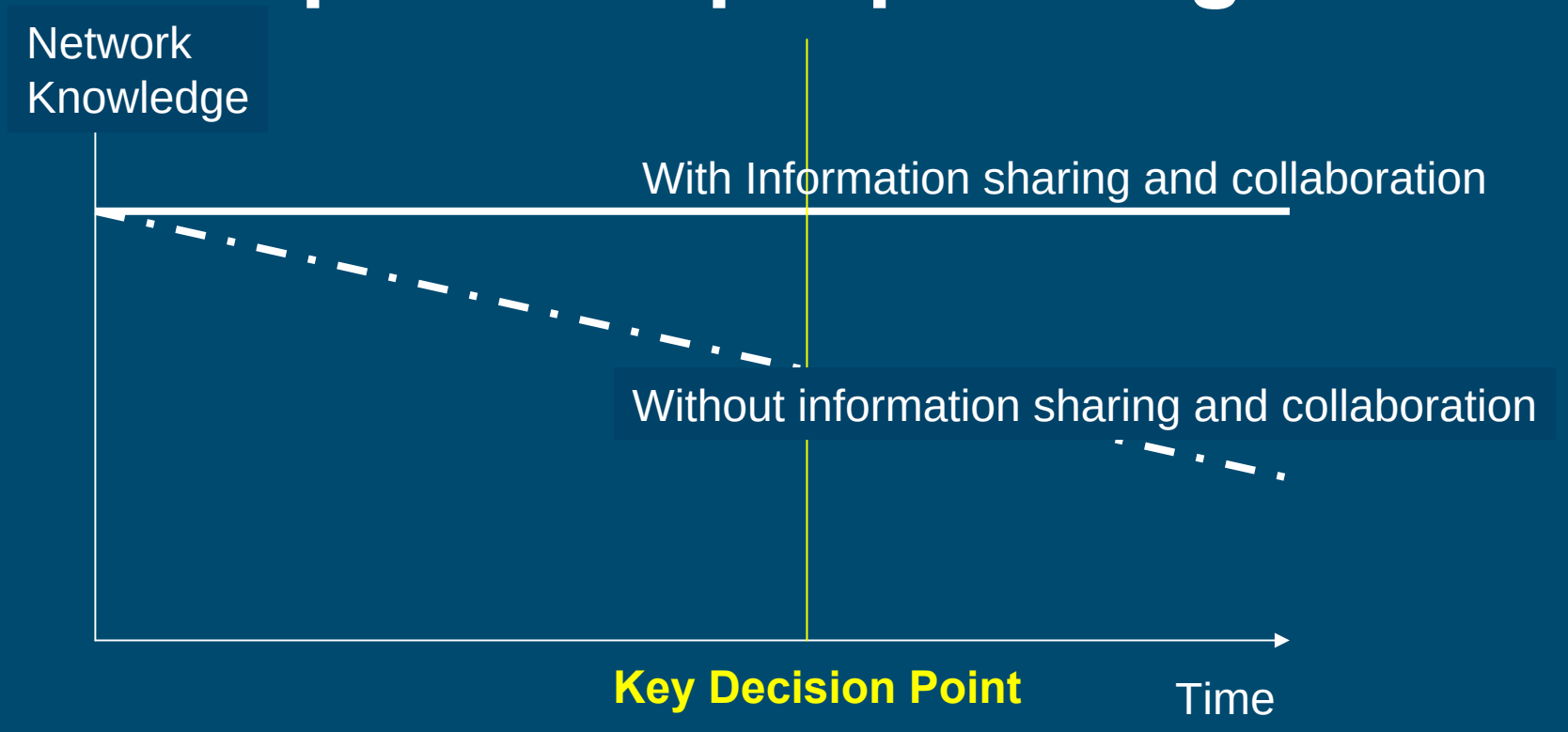
network enabled warfare/Information age warfare



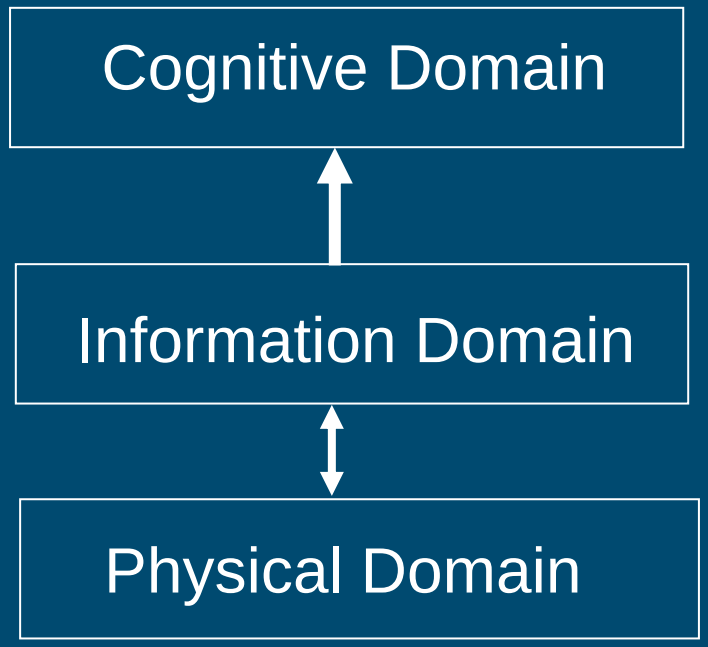
A Network of Decision Making Nodes



Increased Network Knowledge improves rapid planning



Information Superiority Reference Model

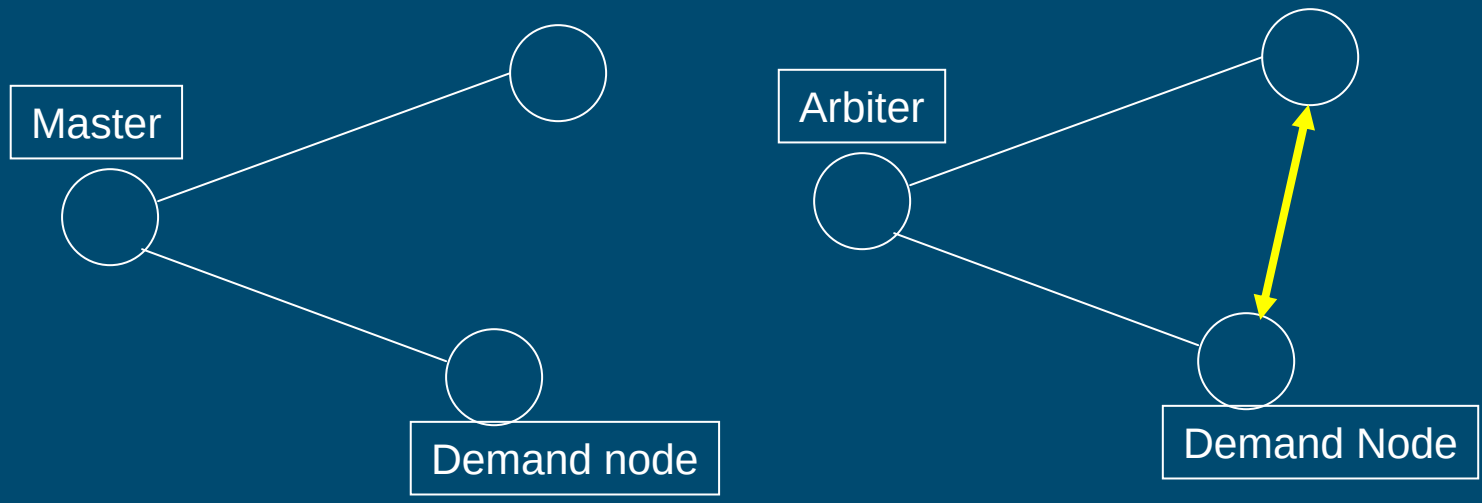


Knowledge

Information

Collaboration Across the Network

Simple Example of Collaboration - Fuel Demand at Two Nodes

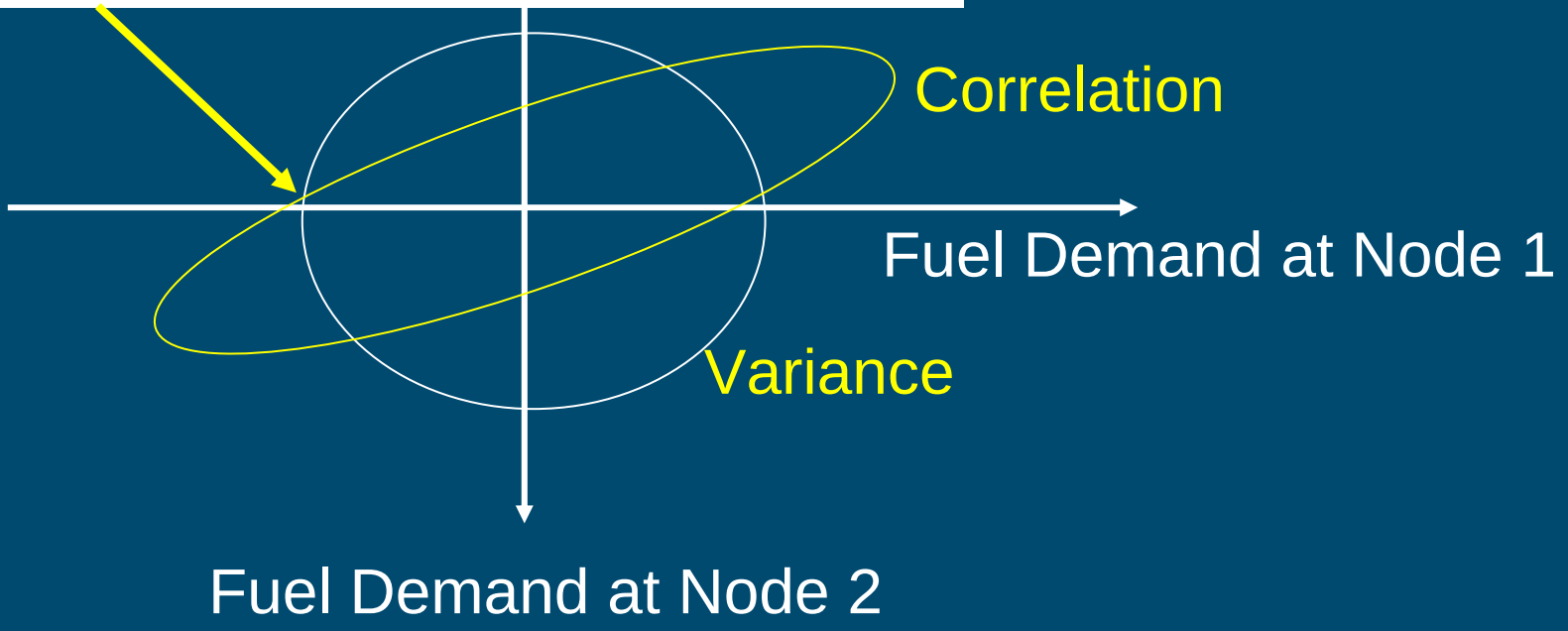


The Benefit of Collaboration

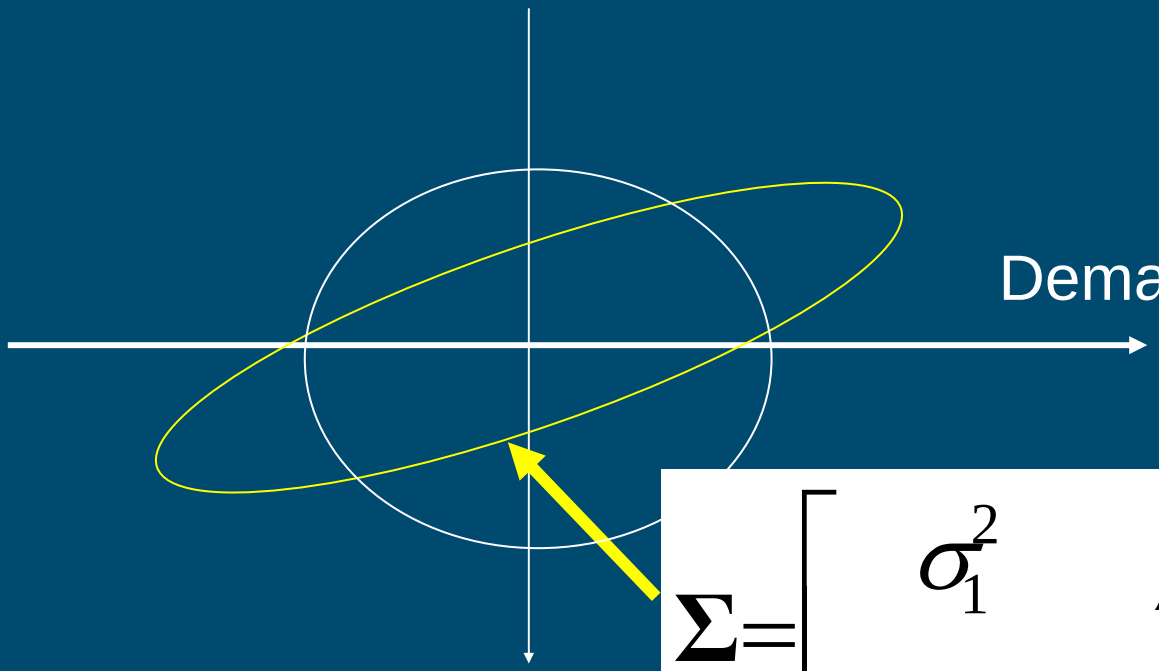
- Precision
  - The ability of a collaborating team to provide estimates that are very close together
  - It affects the estimate's distribution variance
- Accuracy
  - The ability of the collaborating team to provide estimates close to ground truth
  - It affects the estimate's distribution mean
- Correlation
  - The ability of the collaborating team to understand the way variables relate to each other
  - It affects the estimate's joint probability distribution
- All Contribute to Knowledge

The Covariance Matrix Σ

$$f(\mathbf{X}) = \frac{1}{\sqrt{(2\pi)^N |\boldsymbol{\Sigma}|}} e^{\left(-0.5[\mathbf{X}-\boldsymbol{\mu}]^T \boldsymbol{\Sigma}^{-1}[\mathbf{X}-\boldsymbol{\mu}]\right)}$$



The Covariance Matrix Σ



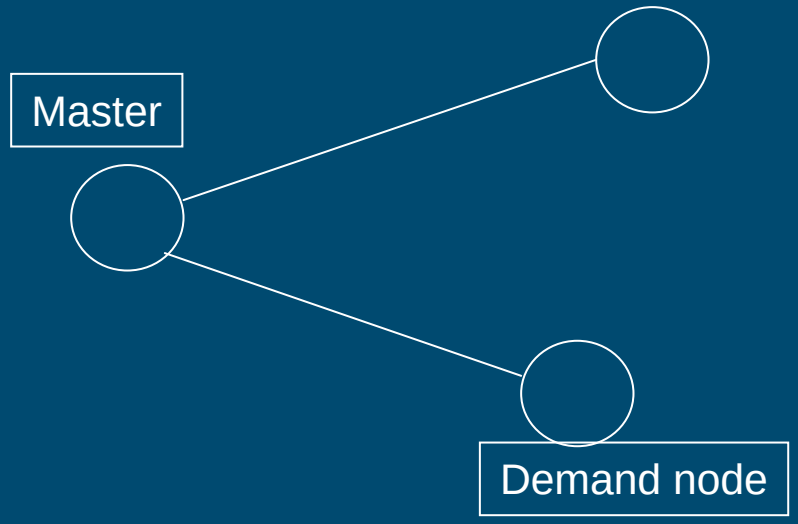
$$\Sigma = \begin{bmatrix} \sigma_1^2 & \rho_{1,2}\sigma_1\sigma_2 \\ \rho_{1,2}\sigma_1\sigma_2 & \sigma_2^2 \end{bmatrix}$$

Information Entropy - Normal Distribution

$$H(\mathbf{X}) = E[-\log f(\mathbf{X})] = -\int_{x_1 x_2} \int \cdots \int_{x_N} f(\mathbf{X}) \log f(\mathbf{X}) dx_N \cdots dx_2 dx_1 .$$

$$H(\mathbf{X}) = \frac{1}{2} \log (2\pi)^N |\mathbf{\Sigma}| + \frac{N}{2} = \frac{1}{2} \log \left[(2\pi e)^N |\mathbf{\Sigma}| \right]$$

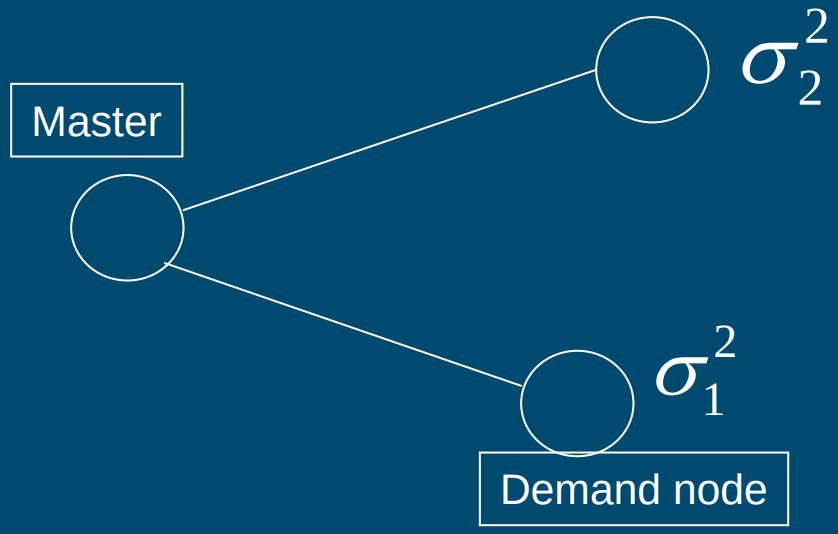
Simple Logistics Example
No Collaboration - No Covariance



Total Entropy = Entropy at Node 1

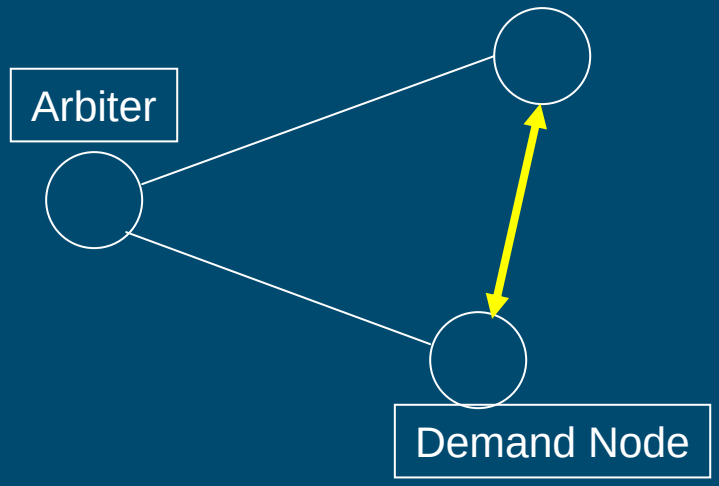
+ Entropy at Node 2

Total Information Entropy - No Collaboration



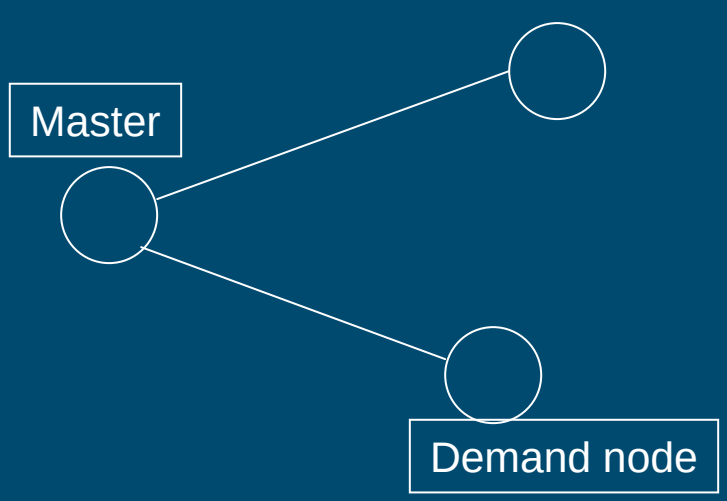
Total Entropy = $Log\begin{vmatrix}\sigma_1^2 & 0\\ 0 & \sigma_2^2\end{vmatrix} = Log\sigma_1^2\sigma_2^2 = Log\sigma_1^2 + Log\sigma_2^2$

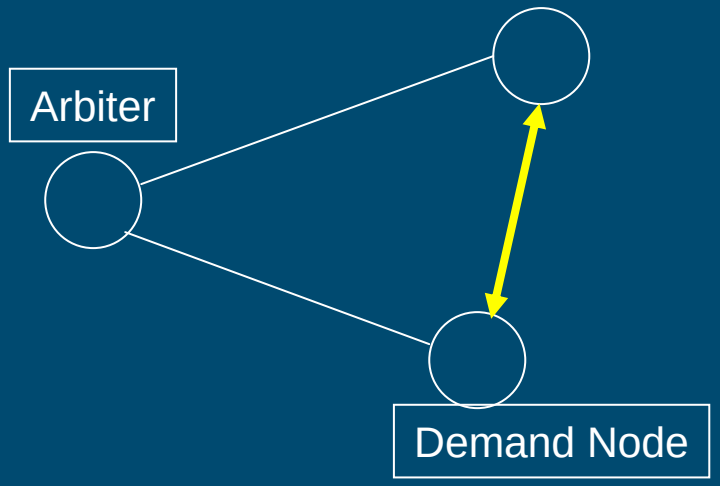
Total Information Entropy - With Collaboration



$$\text{Total Entropy} = Log \begin{vmatrix} \sigma_1^2 & \rho_{1,2}\sigma_1\sigma_2 \\ \rho_{1,2}\sigma_1\sigma_2 & \sigma_2^2 \end{vmatrix} = Log\sigma_1^2\sigma_2^2(1-\rho_{1,2}^2)$$

Entropy Reduction due to Collaboration





Entropy Reduction = $Log(1-\rho_{1,2}^{2})$

Source References

- J Moffat ‘Command and Control in the Information Age - Representing its Impact’ The Stationery Office, London, UK, 2002.
- J Moffat ‘Complexity Theory and Network Centric Warfare’ in press, CCRP, OSD,DoD, USA, 2003.
- W Perry, J Moffat ‘Information Sharing among Military Headquarters; The Impact on Decision Making’ in press, RAND Corporation DRR-2965-UK, 2003.

Challenges for the information age

- Quantifying the benefit of good Command
  - command effectiveness/force effectiveness
- Understanding Emergent Behaviour
  - local collaboration/force level effects
- Modelling the clustering of decision makers across an information network
  - local information sharing/collaboration